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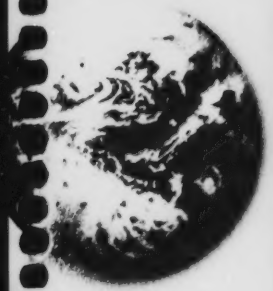

Canada

Environmental Technology Centre
Biennial Report 1998/2000
April 1st, 1998 to March 31st, 2000

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Notice

A special note of thanks to Francine Payne for co-ordinating this report and to the following for preparing and reviewing the text: Dr. Jacqueline Bélanger, Dr. Carl Brown, Paul Brunet, Cindy Burton, Mike Bumbaco, Dominic Cianciarelli, Dr. Merv Fingas, Fred Hendren, Dr. Don MacGregor, Brian Mansfield, Dr. Jocelyn Paré, Richard Scroggins, and Dr. David Thornton. The text was edited by Jennifer Charles.

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Any comments on the contents of the report - or requests for additional copies - should be directed to:

Office of the Director
Environmental Technology Centre
Environmental Technology Advancement Directorate
Environmental Protection Service
Environment Canada
3439 River Road South
Ottawa, Ontario K1A 0H3

Tel: (613) 991-5633
Fax: (613) 998-1365
E-mail: payne.francine@etc.ec.gc.ca
Web page: www.etcentre.org

Pour une copie de ce rapport en français, veuillez vous adresser au:

Bureau du Directeur
Centre de technologie environnementale
Direction pour l'avancement des technologies environnementales
Service de la protection de l'environnement
Environnement Canada
3439, River Road sud
Ottawa, Ontario K1A 0H3

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A Message from the Director

Since the mid-1970s, the Environmental Technology Centre (ETC) has dedicated itself to advancing science and using technology for the protection of the environment. Much of the Research and Development (R&D) and some of the specialised scientific support are undertaken through collaborative arrangements with the private, public, and academic sectors.

Close to 170 people work at the Centre, including more than 90 staff members, approximately 70 contractors, and about 10 research associates, post-doctoral fellows, and students. In a typical year, the base scientific operating budget received from the Department is between $6 and $7 million, with up to an additional $5 to $7 million received from joint-project agreements, intellectual property revenues, or other special funding arrangements. Another $10 to $15 million is invested by collaborators through work-sharing and in-kind arrangements.

Our Centre provides scientific support and R&D services to Environment Canada's programs, specialising in:

- technologies for measuring air pollutants in ambient air and from mobile and stationary sources;
- analysis of a wide variety of organic and inorganic compounds in diverse samples;
- assessment and cleanup of contaminated sites;
- prevention of and response to environmental emergencies such as oil and chemical spills; and
- development and assessment of environmentally friendly technologies.

The R&D and technology transfer often involve international partners. My colleagues and I host hundreds of visitors each year from all parts of the globe, providing direct technology transfer and marketing opportunities for Canadian R&D and technology to decision-makers and R&D managers from around the world.

Innovative technologies for chemical extraction invented by some of the Centre's scientists have had a beneficial impact on the environment. In a laboratory setting, these technologies have dramatically reduced energy/solvent consumption, processing time, and waste production, as well as increased extraction yields and purity.

The rationale and results of the major activities conducted at the ETC from April 1, 1998 to March 31, 2000 are described in this Biennial Report. The Centre's mission and roles are described in Appendix A and a list of patents is provided in Appendix B. Scientific reports and papers presented or published during this reporting period are listed in Appendices C to F.

In closing, all of us at ETC carry out our mandate through hard work and dedication. We share a strong sense of responsibility for preserving a better future for generations to come and we will continue to focus our efforts in this direction. We are committed to working together to advance science and use technology to protect the rich diversity and breathtaking beauty of our environment.

Dr. David E. Thornton

Table of Contents

A Message from the Director iii

1. Organisational Structure and Division Mandates 1
- 1.1 Environmental Technology Centre (ETC) 1
- 1.2 Analysis and Air Quality Division (AAQD) 2
- 1.3 Emissions Research and Measurement Division (ERMD) 2
- 1.4 Emergencies Science Division (ESD) 3
- 1.5 Emergencies Engineering Technologies Office (EETO) 4
- 1.6 Special Programs Division (SPD) 5
- 1.7 Microwave-Assisted Processes Division (MAP) 5

2. Ambient Air Monitoring and NAPS Network 7
- 2.1 National Air Pollution Surveillance (NAPS) Network 7
- 2.2 Support to the Smog (NO_X/VOC) Management Plan 8
- 2.3 Particulates Monitoring Program 9
- 2.4 Research in Application of Ion Chromatography and Capillary Electrophoresis . 10
- 2.5 VOC Monitoring and Research Program 11
- 2.6 PAH and Dioxins/Furans (PCDDs/PCDFs) Monitoring Program 12

3. Measurement of Toxic Substances 15
- 3.1 Determination of Nitro-PAH in Ambient Air 15
- 3.2 Level of Quantification (LOQ) for HCB and Dioxins in Gas Emissions and Soil 15
- 3.3 Development of Dioxin Reference Materials 16
- 3.4 Characterisation of Carbonaceous Particles 17
- 3.5 Development of an Analytical Method for Measuring HCB in Ferrous and Ferric Chloride Solutions 17

4. Measurement of Emissions from Stationary Sources 19
- 4.1 Reference Methods and Recommended Methods for Source Testing 19
- 4.2 Support to Environment Canada Regulatory Programs 20
- 4.3 Support to Environment Canada Inventory Programs 22
- 4.4 Source Emissions Evaluation and Technology Assessment 26
- 4.5 Quality Assurance/Quality Control (QA/QC) and Technical Support 29

5. Measurement of Emissions from Mobile Sources 31
- 5.1 Support to Regulatory and Inventory Programs 31
- 5.2 Support of Greener Technologies 35

6. Support to Spill Response 39
- 6.1 Summary of On- and Off-site Assistance 39
- 6.2 Spills/Incidents at which ETC Assisted 40

7. Spill Measurement, Behaviour, and Effects 43
- 7.1 Airborne Remote Sensing Operations 43

7.2 Oil Detection Using Laser Fluorosensors 43
7.3. Airborne Oil Slick Thickness Sensor 43
7.4 Spill Modelling 44
7.5 Chemical Spill Analytical Projects 44
7.6 Oil Properties and Analysis 44
7.7 Behaviour of Spilled Oils (BOSS) Project 45
7.8 Testing of Spilled Substances/Development of Biological Methods 45
7.9. Environmental Fate, Behaviour, and Effects of Oil 46
7.10 Post-spill Monitoring 46

8. Spill Countermeasures R&D 47
8.1 In-situ Burning 47
8.2 Chemical Spill-treating Agents 48
8.3 Evaluation of Sorbents 48
8.4 Evaluation of Mechanical Containment and Recovery Equipment 48
8.5 Development of Standards 49

9. International Transfer of Canadian Technology 51
9.1 Australia 51
9.2 Brazil 51
9.3 Chile 51
9.4 India 51
9.5 Hong Kong 51
9.6 Mexico 52
9.7 Pakistan 52
9.8 Poland 52
9.9 Netherlands 52
9.10 U.S. 52
9.11 Ukraine 53

10. Technologies for Decontaminating Water 55
10.1 Electrochemical Treatment of Acid Mine Drainage and Potential Applications to Site Remediation 55

11.Technologies for Decontaminating Soil 57
11.1 Potential Remediation of Sediments from Tar Ponds 57
11.2 Destruction of Chlorinated Organic Compounds in Soil 57
11.3 Two-phase Partitioning Bioreactor for Soil Remediation 57

12. Advancement of Science and Technology 59
12.1 Good Laboratory Practice (GLP) 59
12.2 Method Development and Application 60
12.3 Environmental Management System (EMS) 61
12.4 Quality Assurance/Quality Control (QA/QC) 62

13. Commercialisation of Environment Canada's Patented Microwave-Assisted Processes (MAP™) 65
13.1 What is MAP? 65
13.2 Licensing of the Various Applications of the MAP Technology 66

13.3 Enhancement of International Exposure of the MAP Technology 66
13.4 MAP™ Centre of Excellence 66

14. Development of MAP Analytical Methods and Instrumentation 69
14.1 Official MAP Methods 69
14.2 MAP Water Quality Measurement Technologies 70
14.3 Removal of Contaminants from Soil Using the MAP Technology 70
14.4 Enhancement of MAP Extraction Efficiency Using CO_2 under Liquid and Supercritical Fluid Conditions for Industrial Purposes 71
14.5 MAP Laboratory-scale Extraction Equipment 71

15. Development of Industrial Applications of the MAP Technology 73
15.1 Design, Construction, Modification, and Testing of MAP Pilot Plant Process 73
15.2 Design and Construction of MAP Bench-scale Process 73
15.3 MAP Industrial Product Development and Testing 74

16. MAP - A "Green" Technology 75
16.1 MAP and Greenhouse Gas Emissions 75
16.2 MAP/Climate Change Action Fund 75
16.3 MAP/Collaborations 75
16.4 MAP/Green Chemistry/Pollution Prevention 76

17. Compliance Enforcement 77
17.1 Dioxins in Pulp and Paper Mill Effluents 77
17.2 Analysis of PCBs 77
17.3 Defoamer and Wood Chip Regulations 77
17.4 Analysis of Ozone-depleting Substances (ODS) 77

18. Support to the Development of Canada-Wide Standards (CWS) under the CCME's Federal-Provincial Harmonisation Accord 79
18.1 Petroleum Hydrocarbons (PHC) in Soil 79
18.2 Particulate Matter (PM) and Ozone 79
18.3 Benzene 79
18.4 Polychlorinated Dibenzo Dioxins and Furans (PCDD/PCDF) 80

Table
1 Spill Incidents at which ETC Assisted (April 1998 to March 2000) 41

Figures
1 MAP Pilot Plant Unit Schematic 73
2 MAP Bench-scale Unit 74

Appendices

A The Environmental Technology Centre (ETC) – Mission and Roles 81
B List of Patents 83
C Published Papers, Books, Book Chapters, Articles, and Reviews 85
D Manuscript Reports (Unedited) 91
E Conference Proceedings 97
F Scientific Presentations 107
G ETC Staff Members 113
H List of Acronyms (English and French) 117

1. Organisational Structure and Division Mandates

1.1 Environmental Technology Centre (ETC)

The Environmental Technology Centre (ETC) of Environment Canada (EC) was established in the mid-1970s to provide specialised scientific and R&D support for the department's environmental protection activities. The Centre advances science and develops technology in the following areas: technologies for measuring air pollutants in ambient air and those emitted from mobile and stationary sources; the analysis of a wide variety of organic and inorganic compounds in diverse sample matrices; remedial action for hazardous waste sites; prevention of and response to environmental emergencies such as oil and chemical spills; and collaborative development of "clean" laboratory and industrial processes.

Most of the R&D work and some of the specialised scientific support services are undertaken in collaboration with other government organisations, the academic sector, and private industry. Much R&D work is undertaken in co-operation with international partners. Contractors working on- and off-site perform a significant part of the work, as does an ongoing Alternative Service Delivery (ASD) contractual arrangement for the Emergencies Engineering R&D work. The official Mission of the ETC is included in Appendix A.

Project results are documented in informal (unedited) manuscript reports and formal (edited) reports available in both official languages. In addition, staff members contribute technical and scientific papers to journals and to proceedings of conferences and workshops. A list of patents, reports, and papers from the Centre during this review period is included in Appendices B through F. A list of staff members and how to reach them is provided in Appendix G and acronyms are listed in Appendix H.

At the Centre, the *Director's Office* is responsible for the overall direction of ETC programs and for central services such as administrative support. In addition, co-ordination of special issues is undertaken on occasion. The scientific, laboratory, and field capabilities of the Centre are divided among the following six scientific Divisions:

- Analysis and Air Quality Division
- Emissions Research and Measurement Division
- Emergencies Science Division
- Emergencies Engineering Technologies Office
- Special Programs Division
- Microwave-Assisted Processes Division

1.2 Analysis and Air Quality Division (AAQD)

The *AAQD* is responsible for co-ordinating the operation of the federal-provincial National Air Pollution Surveillance (NAPS) Network, which consists of 400 air-monitoring instruments at 150 sampling stations located in 52 major urban centres in Canada. Air quality data are published and disseminated to monitor and assess the quality of ambient air in Canada. The Division also evaluates and develops new ambient air pollution measurement technology in support of the NAPS network and priority issues such as Long-range Transport of Air Pollution (LRTAP), Air Toxics, Smog and development of Canada-Wide Standards.

The Division measures a variety of organic and inorganic compounds in diverse sample matrices, such as from air pollution-related sources, contaminated soils, hazardous wastes, and other residues. Analytical methods are also developed to ensure that the most appropriate procedures are available for specific sample types and to support the development of environmental regulations. The Division is also engaged in Regulatory Compliance and Quality Assurance activities in support of internal and external programs.

The *Organic Laboratory* measures ultra-trace levels (parts per trillion - ppt, parts per quadrillion - ppq) of many organic compounds, with particular emphasis on the analysis of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and other priority pollutants. A specially designed and operated Organic Ultra-Trace Laboratory is used for sample preparation and analysis of these toxic pollutants. The laboratory also carries out analytical projects in support of national programs like the Enforcement Program, develops Analytical Reference Methods to support *CEPA* regulations, designs and implements inter-laboratory studies to validate analytical procedures, and manages quality assurance/quality control (QA/QC) and method development programs to ensure that data generated by contract labs are of the highest quality. It also undertakes special studies such as the development of Levels of Quantitation used for "virtual elimination" under *CEPA* and the Toxics Substances Management Policy.

The *Inorganic Laboratory* develops and applies ultra-trace methods for determining the presence of elements and anions in air particulate matter. The principal techniques used are X-ray fluorescence and ion chromatography. X-ray fluorescence is used to analyse 40 elements (aluminium up to lanthanum and lead). Ion chromatography is used to analyse ten major anions, including the "acid rain" components sulphate and nitrate, and ten cations (alkali metals, ammonium, and earth alkali metals). The Laboratory organises and participates in round-robins at the national and international level to promote improvements in the capabilities of Canadian analytical laboratories. In addition, the Laboratory performs legal analyses for the regional offices of Environment Canada and provides advice on analytical equipment and methods to private industry and government laboratories.

1.3 Emissions Research and Measurement Division (ERMD)

For more than two decades, the *Emissions Research and Measurement Division* has played a leading national role in measuring polluting emissions. The team of engineers, chemists, and

technologists conducts laboratory and field studies of air pollution originating from mobile and stationary sources. The primary focus of the group is to undertake activities in support of departmental issues such as Climate Change, Smog, Toxics, Regulatory Compliance and Enforcement. Some of the activities include:

- characterisation of emissions from sources such as incinerators, boilers, kilns, smelters, stacks, marine vessels, aircraft, off-road vehicles, and utility engines;
- measurement and characterisation of greenhouse gases and organic emissions from municipal landfills;
- evaluation of process control technologies;
- evaluation of remediation and waste destruction technologies;
- quality assurance/quality control;
- development of Reference Methods; and
- advice and assessment.

The Division conducts the compliance and audit testing of new-model, light-duty vehicles and motorcycles under a collaborative agreement with Transport Canada, the administrator of the regulations. [Note: Effective in fiscal year 2000/2001, the new-vehicle and engine emissions regulations are administered by Environment Canada under new authorities in the *Canadian Environmental Protection Act (CEPA)* 1999.]

The Division also provides support to industry through collaborative programs for the research and development of new technologies that help to reduce pollution. These collaborative projects involve the evaluation of:

- alternative and reformulated fuels for light-duty passenger cars and trucks;
- alternative fuels and after-market exhaust emissions control equipment for on-road, heavy-duty vehicles;
- electric and hybrid vehicles, both light- and heavy-duty; and
- new sampling and analysis instrumentation for stationary source emissions testing.

1.4 Emergencies Science Division (ESD)

The *Emergencies Science Division* undertakes research on the properties, behaviour, and effects of spilled hazardous materials and the effectiveness and environmental benefits of in-situ countermeasures such as spill-treating agents, burning, and bioremediation. Such information is used to develop research and operational models that predict the behaviour and fate of untreated and treated oil and chemical spills. Research and development is also carried out on techniques for measuring contamination in air, water, and soil at spill sites and on technologies for airborne remote sensing of spills.

The Division prepares technical spill-response guidelines and manuals for use by emergency response personnel and contingency planners and serves as the primary centre of scientific advice on pollution emergencies to the regional offices of Environment Canada and other organisations. For spills of national concern, this role includes direct involvement in response operations through the provision of information and predictions about spill behaviour, fate and effects,

airborne remote sensing services, on-site specialised sampling, and analytical support. Training in the use of personal protection equipment and portable hazard-level monitoring equipment is also provided to departmental emergencies personnel and to other responders.

The Division co-ordinates the preparation of the biannual *Spill Technology Newsletter* and organises the annual international Arctic and Marine Oilspill Program (AMOP) Seminar, the Technical Seminar on Chemical Spills (TSOCS), and the Phytoremediation Technical Seminar.

1.5 Emergencies Engineering Technologies Office (EETO)

This office, and a new competitively awarded contractual arrangement for Alternative Service Delivery by a private contractor, has essentially replaced ETC's internal organisation, which was previously known as the Emergencies Engineering Division (EED).

For the past two decades, EED has undertaken engineering research, development, and demonstration work on technologies for cleaning up contamination caused by pollution emergencies, such as oil or chemical spills and insecure hazardous waste sites. This work includes R&D on, and evaluation of, sorbent performance and containment, recovery, and disposal equipment for response to oil and chemical spills in marine and non-marine environments. It also includes development, dissemination, and use of testing protocols for evaluating spill-response equipment in the lab and the field.

The Division develops and maintains a range of prototype mobile cleanup equipment that is used, in co-operation with others, to demonstrate and adapt innovative methods for on-site mitigation of water or soil contamination, which is difficult to handle using conventional techniques.

The Division has served as the primary centre of specialised engineering advice on pollution emergency cleanup to the regional offices of Environment Canada and other organisations. For spills of national concern, this could include direct involvement in cleanup operations through the provision of on-site expertise and unique mobile water- or soil-decontamination equipment. It also involves the transfer of Canadian technologies overseas in collaboration with companies in the private sector.

As a result of an extensive Alternative Service Delivery (ASD) study and a competitively bid transition process initiated in January 1997, this Division became a privatised contractor group on April 1, 1998. The new group continues as a technology R&D partner of Environment Canada. Under this arrangement, the research studies and technical services are still undertaken as requested, specified, and approved by Environment Canada through an ongoing series of work orders provided for under the contract. External clients can also make separate arrangements to hire the contractor for similar technical services and studies.

The *Emergencies Engineering Technologies Office (EETO)* is the ETC's one-person office responsible for managing the current five-year ASD contract and for the day-to-day technical linkage between the contract group and Environment Canada. The new privatised organisation, still based at the ETC, is now known as the *Environmental Technologies Program of the Emergency and Safety Services Division of SAIC Canada*. The full company name is Science

Applications International Corporation of Canada, which is the Canadian subsidiary of the parent SAIC group initially based in the United States, but now active internationally.

Over the current reporting period, the internally funded ASD contract with SAIC resulted in the undertaking of 24 projects in the first contract year in R&D or Related Scientific Activities/Technical Support for ETC in Emergencies Engineering technologies. The second year involved 22 such projects, some of which were further extensions of work initiated in the previous year.

1.6 Special Programs Division (SPD)

The *Special Programs Division* provides strategic, operational, and policy support to the Director's Office. Two science units in the Division provide input to Departmental regulatory and policy processes by ensuring the availability of scientifically sound test methods (*Methods Development & Application Section*) and by developing a base of Canadian commercial laboratories that can generate internationally accepted data on new substances (*Good Lab Practice Compliance Monitoring Unit*). The Division also manages and co-ordinates programs with Centre-wide application or implications, such as the design and implementation of a comprehensive Environmental Management System (EMS) and a Quality Assurance/Quality Control (QA/QC) system for the Centre's analytical chemistry operations.

The *Good Laboratory Practice (GLP) Compliance Monitoring Unit* provides support to the scientists from the Commercial Chemicals Evaluation Branch in Environment Canada and the Environmental Health Directorate in Health Canada by inspecting Canadian laboratories that provide data in support of New Substances Notifications. The Unit maintains information on the compliance status of overseas GLP laboratories and audits specific laboratory studies at the request of domestic or overseas regulatory authorities. In addition, the Unit is responsible for developing GLP programs and supporting the GLP activities of the Organisation for Economic Co-operation and Development (OECD).

The *Method Development and Application Section* is responsible for forecasting the need for Environment Canada analytical methods and particularly for developing new toxicological methods required for regulation. Priority analytical chemistry methods and performance-based method guidance are developed in conjunction with the departmental Laboratory Managers' Committee. Aquatic and sediment toxicology methods are developed in conjunction with staff from Environment Canada's regional offices, as well as from provincial and private sector laboratories. The Section also develops audit checklists and provides guidance on data interpretation for methods required under the *Fisheries Act* and the *Canadian Environmental Protection Act* (*CEPA*) regulations. As well, the Section provides significant support to the laboratory accreditation program of the Canadian Association of Environmental Analytical Laboratories (CAEAL) in the area of environmental toxicology.

1.7 Microwave-Assisted Processes Division (MAP)

In 1994, the *Microwave-Assisted Processes Division* was formed at ETC to accelerate the development and commercialisation of various applications of Environment Canada's patented

Microwave-Assisted Processes (MAP™). This decision arose from the recognition of the early contribution of these clean processing technologies to addressing climate change issues by reducing greenhouse gas emissions.

Examples of applications of these environmentally friendly technologies include sample preparation techniques for subsequent biological, chemical, and physical characterisation; extraction of high value-added substances from a variety of origins; valorisation of biomass that would otherwise be regarded as a waste product; provision of clean, solventless routes to existing and novel high value-added substances; and exploration of the applicability of the technologies to more recalcitrant problems such as site decontamination.

When developing new applications for the technologies, staff of the *MAP Division* work closely with the various licensees of the technologies and with other interested parties and stakeholders. The Division's work can be divided into two main areas – development of analytical methods and of industrial-scale processes.

In the area of developing analytical methods, the Division led the initiative of developing and validating a MAP-based standard Reference Method for preparing environmental samples. This method has been approved for use in both Canada and the United States (U.S. EPA Method 3546, under SW-846). The MAP method requires about 90% less solvent than is used in conventional methods of sample preparation. This method can significantly reduce toxic chemical releases, as it is estimated that about 100,000,000 L of organic solvents are used in organic analytical laboratories worldwide each year. Furthermore, toxic solvents, such as dichloromethane, currently used in conventional methods can be avoided completely, thus greatly reducing human exposure to these substances.

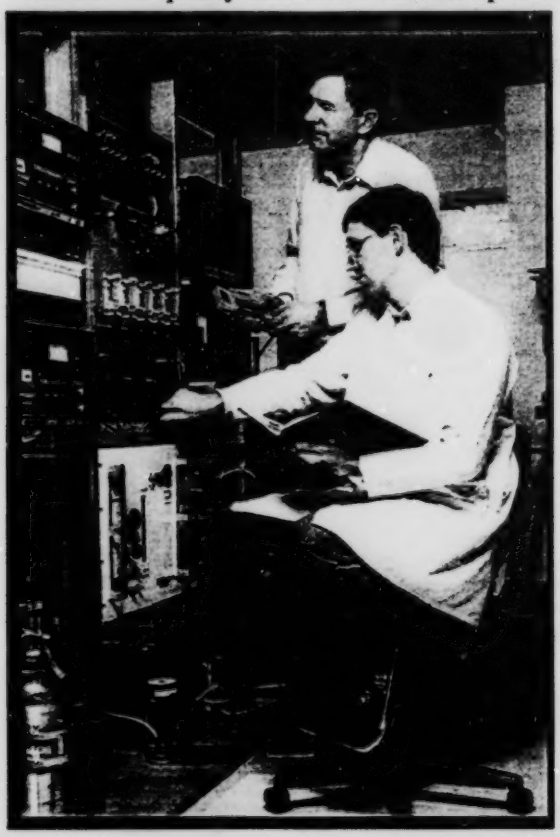
In most cases, energy requirements are also reduced by about 99%, which translates into a significant reduction in greenhouse gas emissions – a major goal of Environment Canada. Processing time is also reduced from between 8 to 16 hours for conventional sample preparation methods to minutes for the MAP method. These environmental, human health, and operational benefits are complemented by economic ones resulting from the savings associated with the reductions in chemicals and energy used as well as the increased throughput achieved in the same amount of technical staff time.

The MAP Division has an established set of procedures to determine the feasibility of various industrial-scale applications of MAP. It begins its feasibility study in the laboratory to evaluate the efficiency of MAP. To date, laboratory testing has been performed on over 100 industrial applications of the technology. Using these laboratory results and, if warranted by the preliminary economic estimates, the applications are then validated using a bench-scale unit where the operational parameters are optimised with respect to the configuration, size, and specifications of potential industrial processes. When necessary, the Division performs pilot-scale testing. Finally, the Division can assist in designing and developing pilot- or full-scale processing equipment and in the initial implementation stages of the actual processing activity.

2. Ambient Air Monitoring and NAPS Network

2.1 National Air Pollution Surveillance (NAPS) Network

The *NAPS* network is a joint program of the federal and provincial governments for monitoring and assessing the ambient air quality at 150 air monitoring stations in 52 urban centres across Canada. Air quality data were collected up to the end of 1999 and were validated and archived in the NAPS database for the following criteria pollutants: sulphur dioxide, carbon monoxide, nitrogen dioxide, ozone, suspended particulate matter, and other pollutants including nitric oxide, TEOM PM_{10} (51 stations), TEOM $PM_{2.5}$ (28 stations), SSI PM_{10} (74 stations), dichotomous PM_{10} and $PM_{2.5}$ (21 stations), suspended particulate lead, sulphate, and various organic compounds (25 stations).



Analysis of calibration gases for NAPS network

The 1997 NAPS annual report was uploaded on the ETC web site in May 1999 and printed for distribution in July 1999. The 1998 NAPS annual report was uploaded to the web site in February 2000 and printed for distribution in March 2000. Several requests for raw and summary data were processed.

In support of development of the NAPS database, a new conversion program for Ontario high-volume and size-selective inlet (SSI) data was developed and improvements to the British Columbia hourly data conversion program were completed. Work has continued on the following projects: NAPS data extractor from the Ingest tables and the Oracle tables and the development of NAPS summary data reports.

Hourly, daily, monthly, and annual statistics on air quality and their status with respect to the national air quality objectives were prepared for the years 1996 to 1998. Technical information and reports were provided to the Pollution Data Analysis Division, the Meteorological Service of Canada (MSC), Environment Canada regional offices, provincial agencies, the U.S. Environmental Protection Agency (EPA), the World Health Organisation (WHO), and various non-government organisations (universities, consultants, and industries).

In support of the NAPS quality assurance program, NAPS stations in St. John's, St. John (2), Halifax, Quebec (2), Calgary (2), Ottawa, and Hull were audited in support of the network quality assurance program. Two assessments of the accuracy of the analysis by the agencies were completed by means of the inter-laboratory comparison of gas concentration analysis.

International comparison of the ozone reference standard with the U.S. National Institute for Science & Technology (NIST) was completed annually. A total of 34 analysers were certified for the network agencies, other government departments, and organisations.

Standard operation procedures (SOPs) were drafted for the weighing of dichotomous filters in determining the concentration of $PM_{2.5}$ and PM_{10} particulate matter in ambient air. The SOPs for the certification of calibration gas mixtures were drafted, finalized, accredited by CAEAL, and approved for inclusion in the Centre's accreditation. The draft of the TEOM particulate monitor operating procedures was finalized and distributed to the operators in the field.

In addition, technical assistance and consultations were provided to the International TransBoundary air quality monitoring project for North Dakota and Saskatchewan and calibration services were provided to other government organisations in Hong Kong, as well as to Health Canada, Agriculture Canada, and non-government organisations.

2.2 Support to the Smog (NO_X/VOC) Management Plan

The purpose of the Science Program of the Canadian Council of Ministers of the Environment (CCME) NO_X/VOC Management Plan is to improve scientific knowledge and understanding of ozone formation in Canada in order to develop appropriate and effective control strategies for NO_X and/or VOCs. The Science Program was started in February 1992 and completed its mandate of producing a State of the Science Assessment Report in December 1997. The Data Analysis Working Group (DAWG), which was chaired by an ETC staff member, was one of eight multi-stakeholder working groups (provincial government, federal government, non-governmental environmental special interest organisation, university, and industry). ETC staff also contributed to reports for the Phase III Smog Plan and the Federal-Provincial Working Group on Air Quality Objectives and Guidelines Science Assessment for ozone.

Analysis of ozone using a primary calibration standard

The NAPS database was the primary source of information required to generate the DAWG Report. The database includes all Canadian observations of ozone (O_3), nitric oxide (NO), and nitrogen oxides (NO_X) for 1980 to 1996. Ozone data for 150 sites in rural and urban United States for 1980 to 1996 are also incorporated into the database. The NAPS database has been converted to ORACLE 7 and is located on a UNIX workstation system in Dorval, Quebec. It has been developed in a common format with the MSC Climate Archive (ATIS/CAP) and EC staff across Canada can access both air quality and meteorological data through common routines.

In January 1998, with the exception of Quebec, ministers on the Canadian Council of Ministers of the Environment (CCME) signed a Canada-wide Accord on Environmental Harmonisation and a sub-agreement on Canada-Wide Standards (CWS). An immediate priority has been placed on the CWS for particulate matter (PM) and ozone and ETC staff are actively participating in a number of initiatives related to this standard. The ETC participates in the following groups which have been set up to manage the Smog issue over the coming years: the Windsor-Quebec City/Southern Atlantic NO_X/VOC Science Group, the Smog Consultation Task Group, and the Working Group on the Tracking System for the Smog Plan. The ETC is also a member of the working group to develop an ozone and particulates annex under the Canada-U.S. Air Quality Agreement.

2.3 Particulates Monitoring Program

Recent health research indicates that airborne particulate matter (PM) is one of the most important air quality problems. Serious health effects, including human mortality, have been linked to particles in the air. Whether directly or indirectly, particles also significantly influence the scope and magnitude of other environmental issues such as visibility, acid rain, and climate change. Particles and their precursors (i.e., gaseous emissions) are produced throughout the processes involved in generating and consuming energy from fossil fuels. These processes include extraction, refining, power generation, heating, and transportation, all of which lead to primary particle emissions. More importantly, they also release gaseous NO_x, SO_2, and volatile organic compounds (VOCs) which react in the atmosphere to form organic and inorganic fine particles ($PM_{2.5}$). Particles in this size range are of greatest interest with respect to human health effects because they penetrate deeply into the lungs. As they contain a relatively high proportion of harmful chemicals and can penetrate indoors, potential for human exposure is high.

NAPS particulate samplers

Monitoring is an essential feature of work on particulate matter because of the need to better understand the health effects of PM through the analysis of high quality time- and spatially resolved data. The promulgation of new and more stringent air quality objectives for PM will require a better understanding of its sources and the tracking of effectiveness of emission reduction measures. As the profile of this issue is raised, the public will require more complete reporting of urban PM levels.

Since 1984, the ETC has co-ordinated a measurement program for PM_{10} and $PM_{2.5}$ using dichotomous samplers. This program also reports 40 elements, measured by Energy Dispersive X-ray Fluorescence (EDXRF) and 21 inorganic and organic ions including sulphate, ammonium, and chloride. Recently developed reliable real-time monitors (the Rupprecht and Patashnick

Tapered Element Oscillating Microbalance or TEOM) that can measure PM_{10} or $PM_{2.5}$ mass are now widely used in Canadian monitoring programs.

As of October 1999, 152 instruments were measuring PM_{10} and 70 instruments were measuring $PM_{2.5}$ in Canada. Forty-seven sites have continuous PM_{10} measurements and 43 sites have continuous $PM_{2.5}$ measurements. At 48 monitoring sites, Environment Canada has either purchased the sampling equipment and/or provides analytical support. All the sites are reporting data to the NAPS database.

A number of special intensive PM measurement activities have been carried out at sites in the Toronto area. Areas of research have included: characterising the carbonaceous fraction of ambient aerosol, comparing manual and automated methods of PM measurement, and investigating losses of nitrate in current sampling methods. Data sets were provided to Health Canada researchers to support a number of ongoing investigations of the relationship between PM components and mortality and morbidity. The ETC is a partner in a Toxic Substances Research Initiative (TSRI) project to study the health effects of urban air pollution mixtures. Sampling began in Toronto and Vancouver in February 2000. The ETC is a partner in another TSRI project entitled "Population Health Impacts of Short-term Exposures to Urban Air Pollution".

The ETC provided support to the Federal-Provincial Working Group on Air Quality Objectives and Guidelines by reviewing and co-authoring the Science Assessment Report, providing all data analysis required to develop the air quality objective numerical value, and providing advice. The ETC provided the required PM data analysis to aid in establishing a draft Canada-Wide Standard for particulate matter.

2.4 Research in Application of Ion Chromatography and Capillary Electrophoresis

Research scientist at work

A research project was started on evaluating methods with radically different selectivity mechanisms for determining low-molecular-mass (LMW) carboxylic acids in a particulate matter and in vehicle emissions. These methods were ion chromatography (IC) with suppressed conductivity detection and capillary electrophoresis (CE) with indirect UV detection. The optimum conditions necessary for the routine CE analysis of airborne and vehicle-emitted LMW carboxylic acids were established. Both methods (IC and CE) were compared. In addition, stability of

the organic acids in the extract of particulate matter has also been investigated. This study was part of two collaborative departmental research programs (PERD and TSRI Projects) related to the determination of the concentration, composition, and sources of airborne carbonaceous particles in Canada.

In conjunction with Carleton University, research continued on the use of a new technology, capillary electro chromatography (CEC), a hybrid technique of micro-packed high-performance liquid chromatography and capillary electrophoresis. The applicability of CEC using a commercially available CE system with photodiode array detection and a 3 μm porous C_{18}-bonded silica capillary column for analysing carbonyl hydrazones was studied. The preliminary applications of this method to samples of ambient air and automobile exhaust show promise for future environmental studies.

2.5 *VOC Monitoring and Research Program*

The major achievement of this program is the production of a high quality database of systematic observations, which is the most extensive long-term data record of its kind in North America. It is now possible to produce nationally representative trend data for a large number of species including those that are important in Climate Change. Results from the program have been used extensively in the *CEPA* Priority Substance List 1 (PSL1) assessment program and in the selection process for the Priority Substance List 2 (PSL2). The ambient air-monitoring program supports both the Ground-level Ozone and Toxics issues and uses the existing federal/provincial infrastructure of the NAPS network. Data from the program were used extensively in developing the Canada-Wide Standard for benzene.

There are more than 45 active urban and rural VOC sampling sites in Canada. During the summer of 1997 and 1998, intensive VOC and aldehyde sampling programs were conducted at Kejimkujik National Park, l'Assomption, Saint Anicet, Mount Sutton, Egbert, and Sutton.

Data were collected in the monitoring program on more than 40 VOCs of concern because of toxicity. Data on compounds selected as candidates for PSL2 were provided to Health Canada and Environment Canada staff. The ETC participated in the PSL2 Resource Groups for 1,3-butadiene, formaldehyde, acetaldehyde, and acrolein. Detailed data analyses were carried out on these substances, as well as on MTBE and hexachlorobutadine.

In the field of toxic VOC research, ongoing support has been provided to the provinces, municipalities, Environment Canada regional offices, Environmental Protection Service Headquarters, other government departments, and universities. Hundreds of requests for data on ambient concentrations of measured species are received annually from researchers in the federal, provincial, and municipal government, as well as in universities and the private sector.

The ETC participated in field inter-comparison studies of formaldehyde measurement techniques at the Centre for Atmospheric Research Experiments (CARE). Scientists from York University, Purdue University, and the Meteorological Service of Canada (MSC) took part. The inter-comparison studies are shedding new light on how organic species are transported and chemically transformed in the atmosphere.

To characterise oxidant precursor emissions from both mobile and stationary sources, the ETC has successfully developed unique VOC analytical methods. The research involved developing means of eliminating water vapour and carbon dioxide interference from collected samples. This makes it possible to characterise source strength relationships for landfill gases and to assess the environmental impacts of burning oil.

A number of joint research projects have been carried out with scientists at the Meteorological Service of Canada to study isoprene emissions from Canadian forests with field studies in Camp Borden, Ontario, Prince Albert, Saskatchewan (Boreal Ecosystem-Atmospheric Study, BOREAS), and Saint Anicet, Quebec. A novel, computer-controlled cryo-concentrator for field analyses was constructed and operated during the field sampling. Calibration standards were also developed for a-pinene and b-pinene and these chemicals were quantified in samples collected at the sites. Assistance was provided to researchers at Agriculture Canada involved in flux measurement of VOC from crops. Results have been published in scientific journals and presented at numerous scientific conferences.

The collected data are allowing the following to be determined: a) total VOC concentrations and the composition of VOC mixtures at rural and urban sites including seasonal and diurnal patterns; b) the relative importance of anthropogenic and biogenic hydrocarbons at urban and rural sites; c) trends in total and speciated VOC concentrations; d) the accuracy of current VOC emission inventories; e) the contribution of specific source categories to determine VOC levels; and f) the adequacy of model inputs and outputs for VOCs. These results have had a significant impact on the overall NO_X/VOC Science Program Assessment and will be used in the Phase 3 Smog Management Plan to determine optimum control strategies and to verify the selection of source categories for control.

The research carried out at Camp Borden revealed substantial production of free radicals, carbon monoxide, and carbonaceous aerosols from the photo-oxidation of biogenic hydrocarbons inside vegetated ecosystems. These are new and important findings. They also point to new areas of research, particularly examining the role of gases such as carbon monoxide (whose tropospheric budget may be underestimated according to the Borden findings) and the interactions between aerosols and the earth's climate system. In that context, during the summer of 1999, an ETC staff member was invited by scientists at the University of Colorado and University of Virginia to participate in a field project in Oak Ridge, Tennessee to verify and augment the findings reported for the Borden forest. The researchers presented their findings at the Gordon Conference on Biogenic Hydrocarbons in February 2000. A comparable GC-MS instrument was also set up in the laboratory of the Environmental Sciences Department at the University of Virginia.

2.6 PAH and Dioxins/Furans (PCDDs/PCDFs) Monitoring Program

In co-operation with Environment Canada's regional offices and provincial environmental agencies, the ETC operates a PAH and PCDD/PCDF measurement program that has collected data from over 35 rural and urban sites across Canada. PCDD/PCDF data are being shared with researchers in the U.S. to determine how much various industrial sectors contribute to ambient levels. A detailed report has been prepared summarising results for the 1987 to 1997 period.

In 1996, at the request of the Ontario Regional Office, the list of compounds was expanded to include a number of additional species that are targeted in the Canada-Ontario Agreement (COA) respecting the Great Lakes basin ecosystem. These include Tier I substances (targeted for virtual elimination) and Tier II substances (persistent, bio-accumulative, and toxic substances of concern) as identified by the International Air Quality Advisory Board of the International Joint Commission. The new COA substances sampling program, which began in September 1996, included nitro-PAH, octachlorostyrene (OCS), hexachlorobenzene (HCB), and pentachlorophenol (PCP). Two new sites were added in rural Ontario and a more frequent sampling schedule was employed. Two reports have been prepared summarising results from Ontario sites for Tier I and Tier II substances and to provide recommendations for future monitoring activities. Urban and rural concentrations are compared as an indicator of source strengths of the species measured.

The ETC is a partner in a Toxic Substances Research Initiative (TSRI) project entitled "Urban Air Toxics: Source Signature and Health Effects". The project will characterise compounds contributing to urban air toxics, develop cost-effective monitoring methods for PAH, PCBs, and other compounds, determine source-receptor relationships, and explore genotoxicity of complex air mixtures. Sampling is being carried out at sites in Toronto and the surrounding areas.

3. Measurement of Toxic Substances

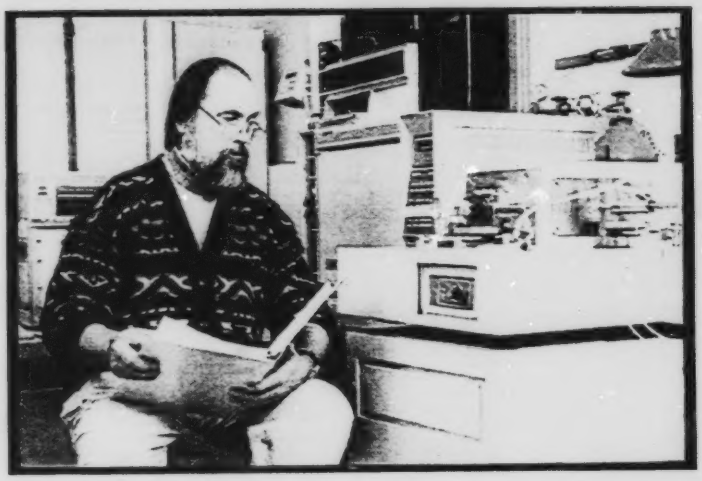
3.1 Determination of Nitro-PAH in Ambient Air

Nitro-polycylic aromatic hydrocarbons (N-PAH) are mutagenic and some compounds of the group are carcinogenic to experimental animals. Diesel engine exhaust has been the major emission source for N-PAH. However, studies on N-PAH from other emission sources and in ambient air are limited. The lack of adequate sensitivity or selectivity in instruments and the limited availability of native and isotope-labelled standards are key factors that have discouraged researchers from monitoring N-PAH compounds in the environment.

A method using HRGC-HRMS and isotope dilution techniques was developed several years ago. Since then, the number of targeted toxic N-PAH has been increased from 11 to 24 compounds. Surrogates have also been increased from 6 to 9 compounds by synthesis of the labelled N-PAH in-house.

The level of N-PAH in ambient air is normally less than 1% of the corresponding PAH. In order to lower the detection limit, the cleanup method has been modified by using the DMSO (dimethyl sulphoxide) liquid-liquid extraction followed by HPLC fractionation on a silica column. By combining these extensive cleanups with the NICI (negative ion chemical ionization) analytical technique, compounds of interest can be detected as low as 10 pg/sample. Consequently, compounds such as NO_2-anthracene, NO_2-fluoranthene, NO_2-pyrene, NO_2-benzo(a)pyrene, NO_2-benz(a)anthracene, and the three dinitropyrene are now often detected in the hi-vol air samples collected from the seven Ontario sites.

3.2 Level of Quantification (LOQ) for HCB and Dioxins in Gas Emissions and Soil



Technologist analyzing dibenzofurans

Environment Canada has included hexachlorobenzene (HCB) and polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/PCDF) in the list of Track 1 substances - toxic substances that are persistent, bioaccumulative, and anthropogenic. Virtual elimination of the Track 1 substances from the environment is one of the objectives of the Toxic Substance Management Policy.

The Level of Quantification (LOQ) is recommended as a baseline to assist in establishing a virtual elimination target. It is determined

by assessing the variability (standard deviation) of repeated measurements of analytes at a concentration near the detection limit. (Note: The term "Level of Quantification" as defined in *CEPA* is the same as "Limit of Quantification" as defined by the American Chemical Society.)

Gas Emissions - The first part of the study was to assess the variability of sampling and analysis of dioxin emissions using the recent available data. The variability associated with sampling, analysis, and source emission during each test influences the standard deviation derived from the dioxin emission data. A total of 53 sets of low emission data from 36 combustion facilities were selected. These data consisted of 42 sets of sequential tests and 11 sets of dual-train tests. When standard deviations of the emission test were pooled, LOQ (or pooled standard deviation) decreased with the highest mean concentration in the pooled data. Based on the linear correlation between LOQ and the highest mean concentration in the pooled data and the upper limit of the acceptable blank level (10 times detection limit), the LOQ for PCDD/PCDF was estimated to be 32 pg/m^3 TEQ.

The second part of the study was to assess the measurement repeatability of HCB and PCDD/PCDF in spiked blank trains and in fly ashes collected from the following four facilities: municipal waste incinerator, medical waste incinerator, cement kiln, and iron sintering plant. The LOQ is defined as ten times the standard deviation of the repeated measurements. A combined standard deviation of the spiked trains and ashes was used. The LOQ for HCB measurement was estimated as 6 ng/m^3 for an emission sample. The estimated LOQ for PCDD/PCDF measurement was 16 pg/m^3 TEQ for an emission sample.

Soil - Three typical soils, provided by Agriculture and Agri-Food Canada, with unique physical and chemical properties were selected for the study. Each soil was fortified with known quantities of PCDD/PCDF and HCB. A 5-g sample was used for each of the 10 replicate analyses. The concentration of HCB and PCDD/PCDF in each sample represents a level between 5 and 10 times the detection limit. Statistical results suggested that the estimated LOQs for HCB and PCDD/PCDF in soils are 2 ng/g (or 10 ng/sample) and 9 pg/g (or 44 pg/sample) respectively.

3.3 Development of Dioxin Reference Materials

A joint study to develop reference dioxin (PCDD/PCDF) values for two natural standard reference materials (SRMs) has been completed by ETC's Analysis and Air Quality Division and the Analytical Chemistry Division of the National Institute of Standards and Technology (NIST) in the U.S. Study results were presented as a poster at the Dioxin'99 conference in Venice from September 13 to 17. This study involved a round-robin test with14 selected government and private laboratories from Canada, the U.S., Germany, and Sweden participating. Results demonstrated that a good agreement was achieved among laboratories for the Urban Dust SRM 1649a (11% RSD for TEQ) and the Sediment SRM 1944 (9% RSD for TEQ). These two SRMs are the first material certified for PCDD/PCDF by NIST. These standard reference materials will be very useful for laboratories in developing methods and monitoring QA/QC.

3.4 Characterisation of Carbonaceous Particles

A co-operative project has been undertaken among several Canadian government laboratories to study: a) the amount of atmospheric particles contributed by transportation sources in populated areas and b) the impact of transportation fuels and types of vehicles on atmospheric particle loading. In support of these objectives, particles and gases emitted from vehicles must be fully characterised.

The CANMET Energy Technology Centre and laboratories at ETC have jointly developed an extraction and separation scheme to characterise organic compounds in diesel particulate and ambient air samples. After the pressurized solvent extraction of a sample using the ASE extraction apparatus, the extract is fractionated on a deactivated open silica gel column. By eluting the column with selected solvents, three groups of compounds, namely paraffins and biological markers, semi-volatile aromatic hydrocarbons, and highly polar compounds, are collected in separate fractions. Methods are being developed to analyse the aromatic hydrocarbon fraction for 27 polycyclic aromatic hydrocarbons (PAH), 21 polycyclic aromatic sulphur heterocycles (PASH), 13 polycyclic aromatic nitrogen heterocycles (PANH), and 25 nitro-PAH target compounds. While GC-MSD is used for PAH and PASH analysis, high resolution MS is used for analysing PANH and nitro-PAH to achieve low detection limits.

3.5 Development of an Analytical Method for Measuring HCB in Ferrous and Ferric Chloride Solutions

Liquid ferric and ferrous chloride are used primarily in the treatment of wastewater and drinking water. Concerns that trace residue levels of HCB, a Track I substance, may be produced during the manufacturing process prompted the development of an analytical procedure. Various commercial blends were received for analysis. The samples were extracted by selective partitioning into hexane, followed by fractionation on a silica column with final analysis by GC-MS. Samples were spiked with the isotopically-labelled HCB ($^{13}C_6$-HCB) to correct for any losses incurred during sample workup. Method detection limits of 0.04 ng/mL of HCB in ferric and ferrous chloride were achieved. Sample recoveries of $^{13}C_{12}$-HCB were very good, ranging from 62 to 86%.

Other development work is currently underway to determine the feasibility of applying the "greener" analytical technique, Solid Phase Micro-Extraction (SPME) to the analysis of HCB in liquid ferric/ferrous chloride solutions. The advantages of this technique are shorter preparation times and lower energy consumption, as well as minimizing use of solvents and waste incurred. The headspace-SPME technique also eliminates problems due to the corrosive nature of the sample matrix. The work currently in progress is focused on optimising the method detection limit and establishing adequate equilibration times. This procedure would be applicable to other aqueous-based matrices.

4. Measurement of Emissions from Stationary Sources

4.1 Reference Methods and Recommended Methods for Source Testing

The Reference Method for dioxins/furans and PCBs (EPS 1/RM/2) was revised to reflect the change of materials and analytical improvements over the past few years. This Method is also used to determine dioxins, furans, hexachlorobenzene, and polycyclic aromatic hydrocarbons from municipal, hospital, and hazardous waste incinerators, electric arc furnaces, and wood stoves. Further revisions are expected as a result of the Level of Quantification (LOQ) for dioxin and furan emissions from stationary sources.

In support of the federal "Guidelines for Stationary Gas Turbines and Reciprocating Engines", a Reference Method for measuring SO_2, CO, and NO_2 emissions from gas turbines was prepared and distributed to stakeholders for comments. Responses were received from Rolls Royce, SaskPower, Alberta Environmental Protection, and the Greater Vancouver Regional District (GVRD). Comments were incorporated and a method for the measurement of CO and NO_x from gas turbines and reciprocating engines was submitted for publication (EPS 1/RM/36).

Sampling and analytical revisions were completed for the Vinyl Chloride *CEPA* Regulatory Reference Method. The Chemical Industries Division will expedite the publication of the Reference Method.

Technical guidance was provided to the Oil, Gas and Energy Branch (OGEB) on an R&D program with the University of Toronto to develop a Time-of-Flight/Laser Ablation Mass Spectrometry (TOF/LAMS) for the real-time sampling and analysis of inhalable and respirable particulate. The Emissions Research and Measurement Division (ERMD) participated in an Ontario Hydro project at the Thunder Bay generating station to observe and gather information on a $PM_{2.5}/PM_{10}$ sampling method. A $PM_{2.5}/PM_{10}$ sampling head was purchased by ERMD for evaluation from stationary sources. Software was also developed for the operation of the particle sizer.

The Centre conducted a search of available and validated techniques for speciating mercury from stationary sources. There is a great deal of interest in the form of the gaseous mercury present in the flue gas. Although none of the procedures has been finalized to date, the technique developed by Ontario Power Technologies appears to be the best method. Using the Environment Canada procedure for metallic mercury and the Ontario Power technique for oxidized mercury, ERMD has begun preparing a Reference Method for speciated mercury from coal-fired power plants.

In support of the "Guidelines for Green Power Electrical Generation" (ECP-79), the Source Section investigated the modification of sample conditioning techniques to prevent the loss of SO_2 from low SO_2 flue gases. This modified scrubbing technique as well as the inclusion of NO_2 will be incorporated into the revised version of EPS 1/RM/15, "Reference Method for the Monitoring of Gaseous Emissions from Fossil-Fuel-fired Boilers".

The Centre continued to evaluate the applicability of the ambient air SUMMA® canister method for stationary sources. The canister method offers a simple, viable, and more flexible alternative

to the Volatile Organic Sampling Train (VOST) method. With support from in-house analytical expertise (Analysis and Air Quality Division), the canisters were used in the determination of VOCs from a variety of stationary sources including landfill gas, landfill gas combustion equipment, power boilers, and wood stoves.

4.2 Support to Environment Canada Regulatory Programs

4.2.1 ECP-79 Renewable Low-impact Electricity (Green Power Guidelines)

The Environmental Choice Program is issuing guidelines for the generation of low-impact electricity from renewable fuels such as biomass and biogas. The ETC provided input to the guidelines dealing with testing conditions, frequency, sampling conditions, testing methods and feasibility of proposed limits. The testing methods will be used to determine the load point for each rated pollutant.

The ETC has reviewed the Hazardous Waste/PCB Regulation for releases to air and provided feedback to the program manager regarding the proposed limits and protocols.

4.2.2 Hexavalent Chromium Regulation

Technical support was provided for the Surface Finishing Hexavalent Chromium Emission Regulation in the areas of monitoring flow rates into control devices and costs of hexavalent chromium sampling.

4.2.3 Dichloromethane (DCM) Regulation

Technical guidance was provided to the National Office of Pollution Prevention on the Dichloromethane Regulation for the determination of releases of DCM from stationary sources. The ETC has recommended the mass balance approach to determine DCM releases from commercial coating stripping operations.

4.2.4 Code of Practice for Coke Producers

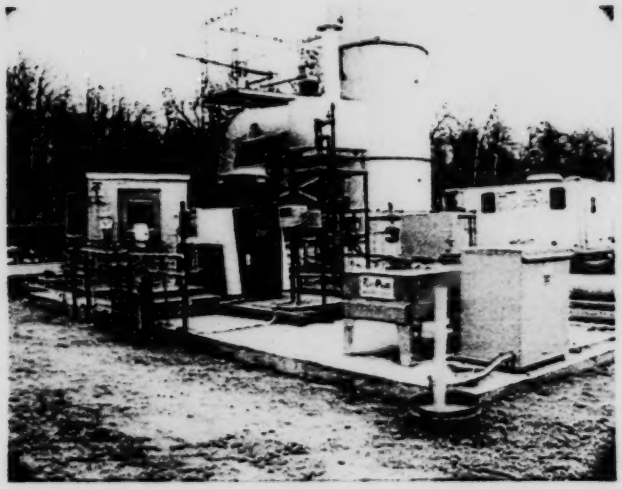
At the request of the Minerals and Metals Division, ETC reviewed the Code of Practice for Coke Producers. More specifically, the Visible Emission Monitoring Protocol for estimating PAH emissions from metallurgical coke production was reviewed and comments forwarded to the Metals and Minerals Division. The ETC recommended various approaches to the qualitative method presently being used by the industry. The "Strategic Options Report for the Steel Manufacturing and Base Metal Smelting Sectors" recommended that protocols be developed for measuring and reporting releases to the environment. The ETC provided scientific review of

industry plans/proposals for monitoring fugitive emissions and provided estimated costs for a comprehensive emissions sampling program to develop protocols for the iron and steel industry.

4.2.5 Level of Quantification (LOQ) Study

The ETC continued to provide input into the determination of the LOQ for dioxins and furans. As dioxins and furans are designated as Track 1 substances under the Toxic Substances Management Policy (TSMP), they are scheduled for virtual elimination. Under this approach, the LOQ will be designated as the target control limit. The LOQ is calculated as ten times the standard deviation of a sample at or near the detection level.

- **Level of Quantification (LOQ) Study for PCBs**



Determination of LOQ from a landfill gas flare

The ETC began a study to determine the Level of Quantification for PCBs from stationary sources. A relatively clean emission source (Trail Road landfill gas incinerator) is being used for the study. A set of 12 sampling trains will be spiked with a low level of a PCB mixture and exposed to the stack gases. A total of 3 to 4 m^3 will be collected in each spiked train and recovered according to the Reference Method. The mixture contains both tri to deca and co-planar congeners. The LOQ is defined as ten times the standard deviation of the repeat measurements.

- **New Brunswick Source Testing Code of Practice**

The ETC provided external technical review of the New Brunswick Source Testing Code of Practice. This document is intended to promote consistency in source testing activities and to ensure that reliable, reproducible, and accurate emissions are submitted to the New Brunswick Department of the Environment.

- **Guidelines for Reporting Environmental Releases Associated with Combustion of Salt-laden Wood Wastes**

Technical review was provided for the guidelines prepared by the Pacific and Yukon Region for reporting environmental releases of dioxins, furans, particulate matter, and criteria gases from hog fuel boilers fired with salt-laden wood wastes. Comments were forwarded to the Pacific &Yukon Region.

- **Ontario Guidelines for Reporting Emissions from Electricity Generation**

Technical review was provided for the Ontario guidelines for reporting continuous emission monitoring (CEM) data and emission calculations and reporting for electricity generation. Comments were forwarded to the Oil, Gas and Energy Branch and formed part of the Environment Canada response to the Ontario Guidelines.

4.3 Support to Environment Canada Inventory Programs

4.3.1 Dioxin, Furan, and Hexachlorobenzene Emissions from the Base Metals and Steel Sector

In April 1995, the Federal-Provincial Advisory Committee for CEPA (CEPA-FPAC) set up the Federal Provincial Task Force on Dioxins and Furans to develop an inventory of sources of releases of dioxins and furans (PCDDs/PCDFs) in Canada and to come up with an action plan consistent with the objective of virtual elimination as per the Toxic Substances Management Policy (TSMP). One key management objective of the TSMP is the virtual elimination of Track 1 substances from the environment. These are toxic substances that result predominantly from human activity and are persistent and bioaccumulative. Both PCDD/PCDF and hexachlorobenzene have been identified as Track 1 substances.

Priority sectors were identified for the development of prevention and/or reduction measures regarding the releases of dioxins and furans and hexachlorobenzene consistent with the objective of virtual elimination. These sectors include base metal smelters, electric arc furnaces, and sinter plants in the steel manufacturing industry. Since there is no North American stack testing data for these sources, the Task Force recommended that Canadian operations be requested to perform representative source testing for PCDDs/PCDFs consistent with that noted in recommendation #6 of the Stakeholder Consultation (Strategic Options) Report for the Steel Manufacturing Sector.

Electric Arc Furnaces (EAF)

In co-operation with Dofasco Inc. and the Minerals and Metals Division of the National Office of Pollution Prevention, the Emissions Research and Measurement Division conducted source testing to determine PCDD/PCDF and hexachlorobenzene emissions from the Dofasco electric arc furnaces. These results will be used to support the dioxin/furan inventory for electric arc furnaces. Further studies are planned at other EAF sites.

Scrap is processed in an EAF to produce steel

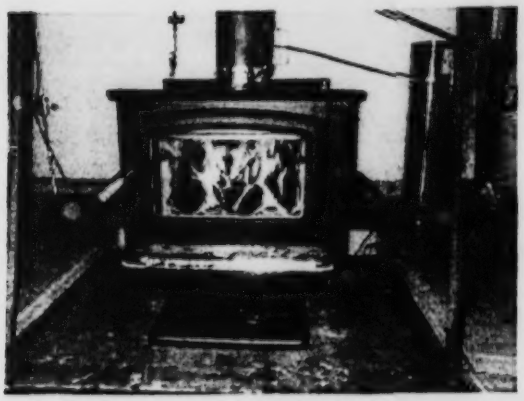
Sintering Plants

Sintering plants have been identified as the largest single source of dioxins and furans in Canada. At the request of the Minerals and Metals Division, the ETC conducted a review of the sampling and interpretation of data for dioxins and furans from the Stelco sintering plant. At the same time, technical guidance was provided to the Region on determining the environmental effects associated with the destruction of dredged sediments in a sintering process.

Base Metal Smelters

At the 1999 annual meeting of the Mining Association of Canada in Ottawa, the ETC made a presentation on the sampling and analysis of dioxins and furans from base metal smelters. As part of Environment Canada's assistance to the mining industry, ERMD reviewed the final report on dioxin and furan testing for a non-ferrous smelter in the Ontario Region. The data from this study will assist in the development of standards and fill data gaps in the inventory.

4.3.2 Dioxins and Furans from Residential Wood Combustion



Measuring emissions from an EPA-certified wood stove

Residential wood combustion (RWC) has been identified as the second largest emitter of dioxins and furans into the atmosphere. In order to develop a reduction strategy for dioxins and furans, it is important to establish the difference in these emissions from conventional wood stoves and those from certified advanced combustion wood stoves to ensure that wood heating is a viable option for Canadians into the 21st century. This will become especially important as we gain more understanding of the potential role of renewable wood heat in meeting Canada's climate change obligations under the Kyoto Protocol. The results of this work will provide guidance to the Canada-Wide Standards (CWS) development process currently underway and update the emissions factors used in calculating air emissions.

This testing and evaluation program was a joint effort among a number of federal and provincial government organizations and industry stakeholders. The main participants included the ETC, the CWS Development Committee, Intertek Testing Services NA Ltd., and the Hearth Products Association of Canada. The overall objective of this project is to compare the emissions of dioxins and furans released from a conventional wood stove with those released from an advanced combustion (EPA-certified) wood stove. Do the lower particulate levels associated with the EPA-certified stove result in lower dioxin and furan emissions?

Each type of wood stove was tested using two types of wood, hard maple (representative of wood burned in eastern Canada) and black spruce (representative of fuels used in northern and western Canada). The testing was carried out in triplicate for each wood stove and each fuel type. In addition to dioxins and furans, samples of the flue gas were collected and analysed for polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and particulate matter.

4.3.3 Releases of Non-methane Compounds from Landfill Sites

The ETC has published a report estimating the releases of non-methane compounds from Canadian landfills. Using ETC measurements and emission factors, releases were determined for dioxins and furans, PAHs, VOCs, mercury, nitrogen oxides, sulphur compounds, and non-methane organic compounds. VOCs included many pollutants considered toxic and carcinogenic under CEPA and listed in the National Pollutant Release Inventory (NPRI). The releases of four VOCs from landfills were greater than the 1996 NPRI release rates to air. Releases of vinyl chloride were 50% higher than the NPRI releases to air. Dioxin, furan, PAH, and mercury emissions did not appear to be significant.

4.3.4 NPRI Inventory for HCl/H_2SO_4

Technical support was provided to the NPRI and the Oil, Gas and Energy Branch for the estimation of releases of HCl and H_2SO_4 from Canadian thermal power plants. The ETC participated in the NPRI annual meeting.

4.3.5 Gaseous Mercury Emissions from Landfill Sites

In co-operation with Ontario Region and the Centre for Atmospheric Research Experiments (CARE), the Environmental Technology Centre is participating in a program to measure the levels of mercury released to the atmosphere from landfills. At present, there is much uncertainty about such release levels. Using cleaned and evacuated stainless steel canisters, ETC staff collected samples of landfill gas from five sites in Eastern Ontario. The landfill gas samples were forwarded to CARE in Egbert, Ontario for mercury analysis using an ambient air gaseous mercury monitor. While the results varied between sites, the preliminary analyses confirmed the presence of mercury in landfill gas. As a result, additional work is planned to validate the sampling and analysis and to collect more samples from landfills.

4.3.6 Tepee Burners

Discussions were held with the province of Newfoundland and Labrador and the Atlantic Region regarding the sampling of tepee burners for the incineration of municipal solid waste (MSW). About 40 of these units, located mostly in remote communities, are operating in Newfoundland. Using emission factors, these units have been identified as a major source of dioxins and furans in Canada.

4.4 Source Emissions Evaluation and Technology Assessment

4.4.1 Environmental Impact of Combustion of Landfill Gases (LFG)

Landfill gases are burned in an internal combustion engine to generate electricity

The Kyoto Protocol encourages the reduction of emissions of greenhouse gases. Landfill gases (LFG), a product of the decomposition of organic waste in landfills, consist of roughly 50% methane. In Canada, six million tonnes of carbon dioxide equivalent is being reduced annually through the combustion of landfill gas. This capture rate could potentially be doubled in Canada.
While the combustion of landfill gases greatly reduces the impact of greenhouse gases, landfill gas contains numerous aliphatic, aromatic, and halogenated compounds. These volatile organic compounds (VOCs) have been identified as major precursors for smog formation, while freons are known ozone-depleting substances. The non-methane compounds also contain vinyl chloride and 1,3-butadiene, which are both carcinogenic compounds.

The effectiveness of flares, engines, and boilers in destroying the non-methane components of landfill gas has only been studied in a preliminary fashion in Canada. As a result, a joint program was initiated between the Waste Prevention Division of the National Office of Pollution Prevention (NOPP), landfill operators, and the ETC. The objective of this program is to evaluate the effectiveness of landfill gas combustors at destroying VOCs and the potential formation of significant substances such as polycyclic aromatic hydrocarbons (PAHs) and dioxins and furans (PCDDs/PCDFs). Others pollutants of interest include particulate matter, HCl, HF, NO_x, SO_2, and CO. This information will be used to improve the estimation of landfill gas releases to the atmosphere.

Three sites were sampled in this program, with the first site sampled in September 1999. The landfill gases from the Meloche landfill in Kirkland, Quebec are sent to Highland Energy Inc. where the gases are introduced to two Caterpillar 3516 engines, which produce 800 kW_e. Power is sold to Hydro Quebec. The second site was located in Ontario. At this site, landfill gases are combusted in two boilers. The last site was the Ottawa-Carleton Regional landfill, where landfill gases are recovered and flared but no power is generated.

4.4.2 Assessment and Quantification of Greenhouse Gases from Active Landfills

In co-operation with the City of Calgary, the Emissions Research and Measurement Division embarked on a three-year program to assess and quantify greenhouse gases from Calgary's three active landfills. Emissions from the landfills will be evaluated during the fall and subsequent spring for three years. The ETC has completed the fall and spring phase of the Shepard landfill and the fall session of the East Calgary landfill in September 1999. The landfill study is part of a City of Calgary corporate program to investigate greenhouse gas emissions generated from existing infrastructure. Reports on the three studies have been completed and forwarded to the City of Calgary. The study will provide valuable information to strengthen national emissions inventories.

At the request of the City of Saskatoon, ETC staff conducted a landfill gas measurement program to determine release rates of methane and carbon dioxide from the surface of a landfill. Samples of gas were also taken from wells for monitoring for volatile organic compounds. A final report detailing the release rates for methane and carbon dioxide and the levels of volatile organic compounds from the wells was completed and forwarded to the City of Saskatoon.

4.4.3 Organic Emissions from Landfill Gases

As an extension of the greenhouse gas measurement program, the ETC embarked on a program to measure VOCs from vented landfills. A wide assortment of aliphatic and aromatic compounds, including halogenated species, is present in landfill gas. These gases are sometimes combusted, which may produce semi-volatile organic species such as PCDD/PCDF and PAH.

To date, the studies have looked at the long-term variations of VOC in landfill gases, variation between sites, and organic profiles before and after flaring. The performance of existing landfill incineration facilities with respect to the destruction of organic compounds was also assessed. Dioxins, furans, and PAHs were also determined from the exit of an LFG incinerator, a candle flare, and a reciprocating engine. Study sites included the Ottawa-Carleton Regional landfill site at Trail Road and four other landfill sites in the Toronto Metropolitan Area, Cornwall, Aylmer, and Montreal.

A program was initiated in 1996/97 to monitor VOCs from landfills on a monthly basis in and around the Ottawa-Carleton Region. These sites include Trail and Ridge Road, Cook Road (Aylmer), Cornwall, and Brockville. This is an ongoing program.

4.4.4 Emissions from the NCR PWGSC Heating Plants

In co-operation with Public Works and Government Services Canada (PWGSC), the Emissions Research and Measurement Division determined the emissions from federal heating plants in the National Capital Region. In total, 23 boilers in six central heating plants were sampled for emissions of sulphur dioxide, nitrogen oxides, carbon monoxide, and oxygen. Each boiler was tested at three load conditions firing with natural gas and oil. Sampling was carried out from January to March 1999. These emissions will result in a database of emissions for federal boilers and will be compared to those from private industry.

4.4.5 Environmental Aspects of Coal Utilization

In co-operation with the Geological Survey of Canada and the Oil, Gas and Energy Branch, the Emissions Research and Measurement Division is participating in a multi-year program to determine the environmental fate of metals and polycyclic aromatic hydrocarbons in coal resulting from weathering, utilization, and precipitation. The studies will take place in power generating facilities in Alberta, Saskatchewan, and Nova Scotia. To date, studies have been completed at the Sheerness and H.R. Milner power-generating stations, which are located in Alberta. These studies will result in a database of elemental and PAH distributions associated with Canadian coals.

4.4.6 National Research Council (NRC) Stationary Turbines

A program was conducted at the National Research Council's Institute for Aerospace Research to characterise polycyclic aromatic hydrocarbons, volatile organic compounds, and carbonyls from the exhausts of three stationary turbine sources. These included the EGT Typhoon single shaft 6,700 HP gas turbine, the Pratt and Whitney 5408 turbofan engine, and the P&W PT-6 twin pack. These sources were tested to assess the impact on the residences in the area surrounding the NRC campus. A report was prepared and forwarded to the National Research Council.

4.4.7 Micro-CHP in Community Energy Systems

The objective of this program is to develop technologies to improve the thermal efficiency and cost-effectiveness of microturbine-generator installations. Testing will be conducted on microturbines from various manufacturers. In December 1998, a Capstone 28kW_e microturbine was sampled at Ontario Hydro Technologies in Toronto for the determination of NO_x, CO, CO_2, and hydrocarbon mass emissions. More tests are planned in 2000.

The program will also develop the application of microturbines to other types of fuels (landfill gas, bio-derived) and to upscale the technology from 25 to 75 kW_e to 200 kW_e.

4.4.8 Flare Burner Research

The ETC is participating in a three-year program with the CANMET Energy Technology Centre to develop a simple but effective enclosed flare burner to replace the flares presently used for solution gas flaring in Western Canada. Design parameters were provided for the pilot-scale test facility and siting of the sampling location. The test facility will be able to test different types of flares and simulate wind speeds of up to 60 km/h. ETC staff will conduct all the organics sampling. This project is being funded by PERD through the Oil, Gas and Energy Branch.

4.4.9 Portage IV Backup Generator

The ETC evaluated the performance of a catalyst for the reduction of CO and NO_x on the exhaust emissions from the diesel backup generator at the Place du Portage IV building in Hull, Quebec. Results were compiled and forwarded to Public Works and Government Services Canada.

4.5 Quality Assurance/Quality Control (QA/QC) and Technical Support

4.5.1 Report EPS 1/PG/7

Report EPS 1/PG/7 covers the protocols and performance specifications for continuous monitoring of gaseous emissions from thermal power generation. The ETC provided technical and logistical support for a Continuous Emissions Monitoring (CEM) course held across Canada and at the Centre. This course transfers CEM knowledge to all organisations affected by the impending regulations and guidelines covering gas turbines, commercial and industrial boilers, and power plants. Fourteen courses have been given across Canada since 1993.

The course covers the principle and operation of a CEM system, the requirements for CEM technology to comply with the proposed CCME NO_x/VOC guidelines, and the use of CEM technology to prevent pollution through better process monitoring and control. In addition to transferring source-measurement technology from the ETC to industry and other levels of governments, the course provides participants from both the private and public sector with a forum to informally share their views and experience and to establish better understanding for future co-operation.

4.5.2 Halifax Incinerator

Technical advice and guidance was provided to the Atlantic Region for performance tests on the Halifax airport incinerator. The incinerator was retrofitted with an afterburner and a wet scrubber. ETC staff witnessed all the testing at the end of March 1999. The final report was reviewed and comments were forwarded to the Region. Results will be used to determine if the operator, D.P. Waste, meets the CCME Guidelines for MSW incinerators.

4.5.3 Calibration

A calibration training session was given to the Ontario Region at the NRC wind tunnel and the ETC labs. The session included calibration of dry gas meters, critical orifices, and pitot tubes.

4.5.4 MENVIQ Accreditation Committee

Discussions were held with the Quebec Department of the Environment (Ministère de l'environnement du Québec/MENVIQ) regarding the establishment of an accreditation of organizations conducting source sampling in Quebec. The ETC will act as an independent advisor to the accreditation committee.

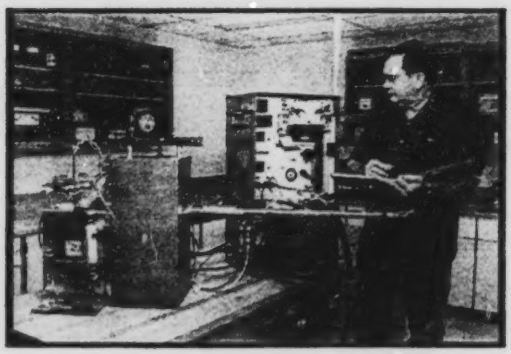
4.5.5 National Inspection Plan and Training of *CEPA* Inspectors

The ETC continues to assist EPS regional offices responsible for implementing the National Inspection Plan by reviewing and commenting on compliance testing proposals/plans, pre-test QA/QC, on-site witnessing/auditing of compliance tests, validating sampling data, and reviewing and making recommendations on the acceptance of the final compliance test reports. Recent joint ETC-Regional projects include compliance/enforcement activities associated with the Secondary Lead Smelter Release Regulations and the CCME Guidelines for Municipal Solid Waste (MSW) Incinerators. Examples include the Cape Breton MSW incinerator in Sydney, Nova Scotia and the Halifax airport incinerator.

4.5.6 Quality Assurance and Quality Control (QA/QC)

A draft report was prepared on a comprehensive Quality Assurance/Quality Control (QA/QC) Manual for manual stack sampling. This document incorporates all aspects of emissions compliance testing such as auditing, witnessing, calibration and, most importantly, safety. While some of this information has already been disseminated to Environment Canada Regions and to the provinces, this document will tie all these topics together.

4.5.7 Auditing and Witnessing Guide for CEPA Inspectors



Manual organic analysis sampling train

The Auditing and Witnessing Guide for CEPA Inspectors was distributed to assist in the ongoing needs of the Regions in implementing the National Inspection Plan. This Guide is intended to assist Environment Canada inspectors to develop a methodical and consistent approach to the auditing and witnessing of emissions tests. The approach described in this guide has been successfully applied to compliance monitoring and high profile programs. The Guide has also been distributed to provincial and municipal monitoring agencies.

5. Measurement of Emissions from Mobile Sources

5.1 Support to Regulatory and Inventory Programs

5.1.1 Compliance Audits and Investigations under the Motor Vehicle Safe ty Act (MVSA) and QA/QC Programs

In collaboration with Transport Canada, the ETC annually conducts exhaust and evaporative-emissions tests and fuel consumption tests on a fleet of approximately 20 new-model, light-duty passenger cars and light-duty trucks. The purpose of the laboratory testing is to audit emissions of total hydrocarbons (THC), carbon monoxide (CO), oxides of nitrogen (NO_X), particulate matter (PM), and evaporative total hydrocarbons for compliance with the federal standards under the *Motor Vehicle Safety Act*. In addition, this testing allows fuel consumption to be accurately calculated and compared with the values provided by the manufacturers.

The testing includes exhaust emission measurements in the ETC Cold Temperature Vehicle Emissions Test Cell at –7 and 24°C. From April 1998 to March 2000, Transport Canada included a total of 12 medium to large displacement motorcycles in the compliance audit program. Representatives from the motorcycle manufacturer Suzuki and the Canadian Association of Motorcycle Retailers visited the laboratory to observe the testing. To support this work, the ETC participates in vehicle emissions testing and reference-gas cross-correlation programs with the major automobile manufacturers and with the U.S. EPA. The ETC also provides test facilities and testing/engineering support to joint industry/government investigations for non-compliant vehicles.

During 1998/1999, there were no compliance failures in the fleet, although a number of vehicles of the same engine family did not meet the fuel consumption recommended by the manufacturer. As a result, Transport Canada initiated a program to obtain and test a number of similar vehicles. This investigation is ongoing.

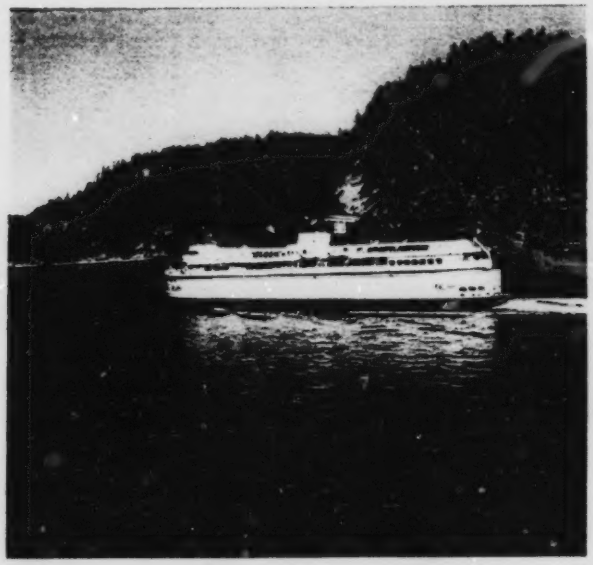
Heavy-duty Vehicle Opacity Tests – Under the Drive Clean Program of Ontario, opacity tests are now required on vehicles equipped with diesel engines. The province therefore established a Quality Control Program for this testing. The first step was to establish a list of test equipment that would meet the requirements of the province, which designated an SAE protocol as the reference. To undertake this task, the province requested ETC to evaluate all of the meters that were made available for the list of approved equipment. Over a three-month period, the ETC conducted extensive testing of 8 opacity meters.

5.1.2 Evaluation of Control Devices and Additives

The ETC undertakes engineering evaluations and occasional laboratory testing of products that are marketed for reducing exhaust emissions and fuel consumption from mobile sources. This testing, which is done on a cost-recovery basis as a service to inventors and distributors, is sometimes conducted as a joint project with a government fleet operator to determine the effect of these products on the emissions and fuel consumption of their vehicles. The ETC provides this

technology evaluation to a number of government organisations in the National Capital Region and the Regions. Operators of a number of other government fleets, e.g., Ottawa-Carleton Transit Authority, Canada Post, and the RCMP also refer to the ETC expertise in this area when discussing products with distributors and inventors.

5.1.3 Marine Vessel Emissions



Queen of New Westminster BC Ferry Fleet

In collaboration with industry, the Transport Canada Strategic Development Centre, and the Pacific and Yukon Region, the ETC initiated Phase II of the Marine Vessel Exhaust Emissions program to evaluate and demonstrate potential technologies for both propulsion and auxiliary marine engines. From April 1998 to March 2000, lab-scale evaluations were conducted on four technologies/concepts and one technology was tested after it was installed on a main engine of the Queen of New Westminster, a vessel in the BC Ferry fleet.

The lab-scale evaluations included: the addition of a platinum fuel additive to improve diesel fuel combustion, continuous water injection for both mechanically and electronically controlled fuel management systems, oxidation catalyst system, and exhaust gas re-circulation based on natural gas engine exhaust. The Phase II program was to demonstrate the reduction in emissions shown during the lab evaluations. Testing of the exhaust emissions was conducted with the system operational, while the vessel sailed on its normal revenue-generating route. The measurements indicated a 15% reduction in oxides of nitrogen with no fuel penalty. This work will continue into the next fiscal year with three new technologies to be investigated.

To determine the contribution of marine traffic to the Vancouver airshed, the Pacific & Yukon Region and the ETC, with support from BC Ferries, undertook a qualitative exhaust emissions characterisation on one of the main engines of the Queen of New Westminster. Samples from the exhaust stream were tested for VOCs, carbonyls, semi-volatiles, and dioxins and furans.

5.1.4 Preliminary Investigations of Emissions from Small Utility Engines

A project was conducted to determine the effect of reformulated fuels on exhaust emissions from a series of engines classified as utility engines. Reformulated gasolines and low-blend ethanol fuels were included in this study. The emissions determination included both the regulated and non-regulated substances, which included volatile organic compounds (C_3 to C_{12}) and carbonyls (aldehyde and ketones).

5.1.5 Pollution from Recreational Vehicles

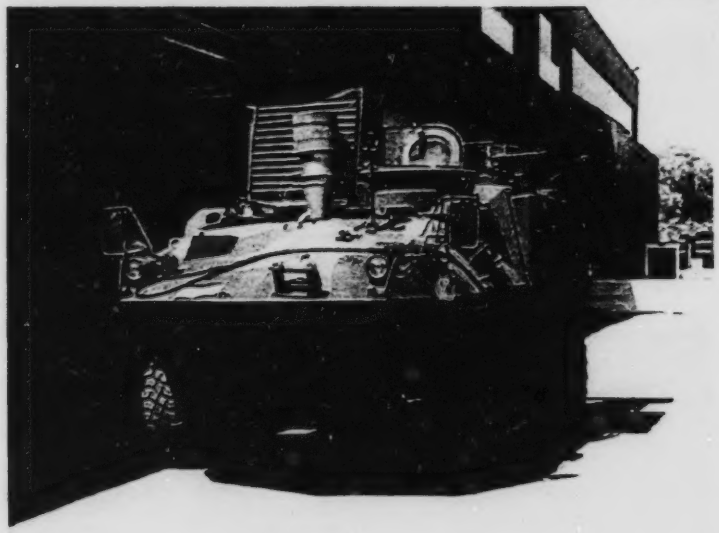
As a continuation of the recreational vehicles program from the previous year, a cross-correlation project was conducted with U.S. EPA's Office of Mobile Source Research in Research Triangle Park. The program involved the exchange of motors between the two facilities for testing regulated and non-regulated emissions, specifically volatile organic compounds.

To develop an inventory of emissions from this source, a number of small displacement motors were tested, including a 9.9 Hp, new technology 4-stroke and an older model 35 Hp.

As part of the work designed to reduce pollution from mobile sources, a joint program was established with a catalyst manufacturer from Newfoundland to develop a system to fit a 2-stroke, 9.9 Hp motor. The unit was installed as part of the exhaust system and tested according to the protocols established by the U.S. EPA. A report is being prepared on the testing and results.

5.1.6 Emissions Evaluations of DND Vehicles

In a joint project with the Department of National Defence (DND), the ETC had performed emissions evaluations at different vehicle maintenance buildings at the Val Cartier Armed Forces Base. As a continuation of this study, the ETC characterised exhaust emissions from DND military vehicles (armoured personnel carrier, tank, etc.) during simulated operational load conditions at the ETC laboratory. A specially designed on-road sampling system was installed on the vehicle to determine the 'tailpipe' exhaust emissions and, in some cases, the interior ambient air quality.



DND armoured personnel carrier

After the first five vehicles were evaluated (Leopard Tank, CI, M109, 10-ton truck, and two Armoured Personnel Carriers), DND requested that an additional five vehicles be evaluated for exhaust emissions. The first two vehicles, an Iltis and a 1¼ ton truck, were tested during this review period. DND also requested that the ETC determine the impact of a diesel particulate trap on the emissions and performance of one of the wheeled vehicles.

5.1.7 Health Canada Garage Emissions Study

As the first phase of a Health Canada/PERD (Panel on Energy R&D), ETC, and CMHC (Canadian Mortgage and Housing Corporation) study to determine the health effects of vehicle evaporative emissions, the ETC conducted laboratory baseline evaporative tests on a vehicle in a simulated garage enclosure at various temperatures. The hydrocarbon samples collected from this

work were characterised for 175 compounds. The same vehicle was then used under 'real' conditions for sampling air in the garage where the car was parked. The migration of hydrocarbon compounds into the interior of the house was then determined.

During this period, nine private homes were also measured for vehicle exhaust emissions migrating into the interior of the house from attached garages. For this study, CHMC conducted air flow studies within the house after which ETC set up specialised sampling equipment to measure migrating emissions at three periods during the day when vehicles are moved in and out of the garage. The sampling and analysis involved determining compounds such as VOCs, carbonyls, and PAHs resulting from the combustion of fossil fuels in internal combustion engines.

The Impact of Traffic on Air Quality in the City Core - A program supported by the Toxic Substance Research Initiative was established with Carleton University and the Region of Ottawa-Carleton to study the air quality at 'nose height' in downtown Ottawa throughout the normal work week, including during rush hour traffic. Sampling systems were designed and fabricated by the ETC to sample the nose height air for a number of toxic compounds including oxides of nitrogen, VOCs, carbonyls, PAH, and total particulate matter. This work was carried out in the colder temperatures of January as it was designed to complement the summer study previously conducted with Carleton University.

A PERD program, with support from the Transportation Systems Branch and the Pollution Data Branch, was conducted to evaluate fine particulates emitted from gasoline-powered vehicles such as passenger cars and motorcycles. A sampling system, which was developed based on cyclone samplers to measure particulates of 1, 2.5, and 10 microns, was used while vehicles were operated in test cells in the laboratory. A second phase of the work involved the analysis of the ambient air using the same sampling system located in a tunnel in the city of Vancouver. Additional support for the tunnel study was provided by the Pacific & Yukon Region, the Greater Vancouver Regional District, the BC Clean Air program, and the University of BC.

Bombardier Recreational Vehicles - To support Canada's entry into the All-Terrain Vehicle (ATV) market, the ETC provided Bombardier with the testing equivalent of the certification requirements of the California Air Resources Board (CARB) and the U.S. EPA. With the results, the vehicles/engines were recalibrated and optimised to meet the U.S. requirements. This work served as an interim solution for Bombardier as they develop their own emissions certification capability.

AMF-ALCO Locomotive Engine - AMF-ALCO is a Canadian company that provides certified engine rebuilds for locomotives across North America. With the introduction of emission reduction requirements for rebuild engines by the U.S. EPA, AMF developed a technology that would meet the new standard. To obtain test data to verify the claims, AMF requested that the ETC conduct field-testing on their 3000 Hp engine as per the accepted protocols. The ETC evaluated two conditions involving fuel injection and inlet air modifications.

Support to Capacity Building in Colombia - Under a Memorandum of Understanding with Instituto Colombiano de Petroleo (ICP) ECOPETROL, the research centre for Colombia's petroleum producer, the ETC provided training and technology transfer to support the upgrading

of a vehicle exhaust emissions test centre. Phase I of this project included 8 weeks of training for two research scientists from ICP and the development of a specialised sampling system for the characterisation of the exhaust stream. Additional requests from Colombia for technology transfer are being considered for the next fiscal year.

5.2 Support of Greener Technologies

5.2.1 Alternative/Reformulated Fuels

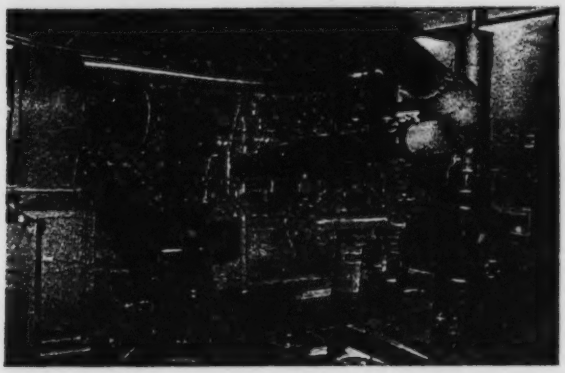
Bio-diesel - To determine the potential impact of bio-diesel fuels on the environment, a joint program was developed by the Transportation Systems Branch (TSB) and the ETC, with support from Health Canada, to characterise the exhaust emissions from a medium-duty, high-speed diesel engine (Cummins 5.9 L). A tailor-blended fuel of 20% methyl ester and 80% low sulphur diesel was used as the test fuel. The exhaust stream was characterised for compounds including VOCs, carbonyls, PAH, and n-PAH. A report was prepared on the testing and sent to both TSB and Health Canada.

Di-Methyl Ether (DME) - In collaboration with Natural Resources Canada, the Transportation Systems Branch, and Advanced Engine Technology (AET), a program was conducted to measure the exhaust emissions from a Cummins 5.9 diesel engine that was converted to operate on DME. Advanced Engine Technology, the prime contractor for the work, developed the direct injection fuelling system for the engine. When operational, the engine was relocated to the ETC laboratory for emissions and performance testing in relation to the OEM diesel operation. As ethers are viewed as a potential replacement fuel for diesel, extensive characterisation was conducted on the emissions stream including VOCs, carbonyls, ethers, and PAHs.

Low-blend Ethanol Fuels - With the increased use of low-blend ethanol fuels (2 to 10% ethanol), a program was initiated with the Transportation Systems Branch to study the effect of the emissions and performance of new model vehicles when the percentage of ethanol in the blend is increased from 15 to 30%. Three vehicles were tested in the ETC laboratory with the higher ethanol blends at standard temperature (25°C) and at cold temperature (-18°C). Some reductions were found in CO_2, NO_X, and CO. Carbonyls, however, were significantly increased. A report is being prepared on this work.

Canadian Oil Sands - Development of Reformulated Diesel Fuels - Syncrude, Shell, PetroCanada, the Canadian Petroleum Products Institute (CPPI), Natural Resources Canada, U.S. DOE, and the ETC jointly supported the evaluation of exhaust emissions on three multi-cylinder diesel engines fuelled with reformulated diesel test fuels, i.e., four matched pairs of Canadian oil sands bitumen-derived fuels and conventional crude-derived fuels. The following three heavy-duty engines manufactured in 1995 were used in this program: a Detroit Diesel Series 50, an N-14 Cummins, and a Caterpillar 3406. Regulated emissions and CO_2 were determined for each test run. Measurements on two of the engines were completed in 1997/98 and the last engine was tested during this review period. A joint Shell Canada, Syncrude, and Environment Canada report has been prepared on this testing.

Heavy-duty Diesel Engine Oxidation Catalysts/Particulate Traps - A program was initiated with NESCAUM (Northeast States for Coordinated Air Use Management) and funded by the U.S. EPA to study the impact on exhaust emissions from off-road vehicles when aftermarket technologies were installed. Laboratory engine testing was conducted of three technologies after in-use operation. The objective of the work was to determine the impact of these technologies after six months of actual off-road trials. The results indicated a significant decrease in emissions reduction efficiency. The results of this work will be included in the final report of the Off-road Project managed by NESCAUM.



Heavy-duty diesel engine

Diesel Particulate Traps - These traps have the potential to reduce the level of particulate matter emissions greater than 10 micrometres by 95%. Although they have demonstrated their effectiveness, durability has been a problem with the traps as they become plugged very rapidly without some means of regenerating the system. A Continuous Regenerating Technology (CRT), developed by Johnson Matthey Inc., will be demonstrated over a two-year period on buses owned by the New York City Transit Authority.

The New York State Department of Environmental Conservation, along with the New York City Transit Authority, Johnson Matthey Inc., Equilon Enterprises, and Corning Inc. developed a plan to equip 40 buses with the technology. Four buses will be used to test the technology for emissions reduction, vehicle performance, and durability. With support from the Ottawa-Carleton Transit Authority, the ETC will provide the testing expertise and the facility for this activity. During the exhaust emissions testing, the ETC will measure regulated compounds, VOCs, carbonyls, and PAH while the State of New York will conduct particle sizing and distribution analysis.

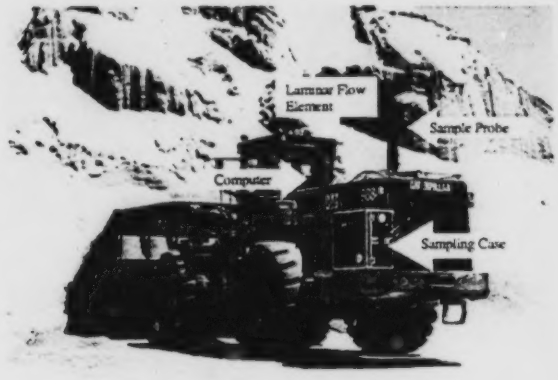
5.2.2 Development of Emission Control Technologies

Industrial Engine Emissions Control Technologies - Propane-powered engines are used in a variety of indoor applications, e.g., forklifts in warehouses and ice-cleaning machines in arenas. In an effort to reduce the pollution from these sources, a Canadian catalyst manufacturing company requested the ETC to test a propane-powered forklift engine equipped with a propane-specific oxidation catalyst. The results provided the company with the necessary operational data to optimise their system for this application.

Development of a Particulate Trap for On-and Off-road Diesel-powered Vehicles - NETT, a Canadian emissions control technology manufacturer, was experiencing sulphation problems with their design for a particulate trap for stationary engines. The ETC was requested to evaluate the designs for various trap substrates on a small, high-speed diesel engine.

The testing consisted of a matrix of substrates and exhaust temperatures in an effort to determine when the sulphate was forming. This work is ongoing.

Reduction of Exhaust Emissions from Urban Buses - Particulate traps for diesel engines were first successfully developed for mining applications. The technology has now been adapted for on-road applications with the focus on urban buses. Johnson Matthey Inc., a manufacturer of particulate traps, has developed a new technology which continually regenerates and clears the particulates that adhere to the substrate. To demonstrate this Continuous Regenerating Technology (CRT), the New York State Department of Environmental Conservation, the New York City Transit Authority, Johnson Matthey Inc., Equilon Enterprises, Corning Inc., and the ETC are participating in a program in which four buses from the New York City Transit Authority will be equipped with this technology for approximately one year. The ETC will provide the laboratory exhaust emissions testing to evaluate the performance of the trap. This is an ongoing project.



Diesel fuel emulsion testing in a salt mine

Diesel Fuel Emulsions - A potential method for reducing emissions of oxides of nitrogen (NO_X) from diesel engines is to add small amounts of water to the combustion chamber. Fuel emulsions are one form of technology that use this method. Lubrizol, a major manufacturer of fuel additives for global markets, developed a water diesel fuel emulsion with a surfactant which is called PuriNO_X® To demonstrate the effectiveness of this technology, a collaborative test project involving the ETC and Lubrizol was conducted at a salt mine near Cleveland, Ohio. The ETC provided specialised sampling equipment for measuring the exhaust emissions from a large diesel engine in a front-end loader, while it operated on normal diesel fuel and then with the fuel emulsion. The results indicated a reduction in NO_X and total particulate mass of approximately 30% and a corresponding loss of 8 to 10 horsepower.

Oxidation Catalysts and Particulate Filters for Heavy -duty Diesel Engines - This multi-year program ended in 1989/1999 as there was no longer a source of funding. Nevertheless, this work was considered invaluable by a Canadian manufacturer of aftermarket emissions control equipment as it provided a venue to demonstrate Canadian technology alongside that of American manufacturers. It also provided Canadian manufacturers of this type of equipment with a means of obtaining invaluable data required for certification under the U.S. EPA's Engine Rebuild Program.

Di-pentyl Ether as a Diesel Fuel Additive - Ethers are being considered as additives for reducing the toxic exhaust emissions normally associated with diesel fuel, i.e., particulate matters and oxides of nitrogen. A co-operative program was established with Health Canada to study the effect on performance and exhaust emissions of combusting a diesel fuel with di-pentyl ether as an additive. Health Canada and the Emissions Research and Measurement Division co-operated

on the sampling and analysis of a series of non-regulated emissions including VOCs, carbonyls, and ethers. A report is being prepared on the results of this project. Additional collaborative work is being planned with targets on other ether compounds.

Natural Gas Continuous-Feedback Fuel-Injection System - The Saskatchewan Research Council, supported by Natural Resources Canada, developed a natural gas fuel-injection system based on a continuous fuel management feedback system. The technology produces exhaust emissions equivalent to the low-emission vehicle (LEV) standards proposed by California. The ETC participated in this work by supporting the exhaust emissions testing to optimise the fuel system. The work included evaluating catalysts, certification and pipeline fuels testing, and the effect of air/fuel ratios. For this review period, the technology became the focal point for a Climate Change Early Action Project for converting original equipment manufacturers' (OEM) vehicles in Romania. Natural Resources Canada has established a program with the manufacturer, Dacia to convert new- model vehicles to natural gas using this clean fuel technology.

5.2.3 Alternative Engines/Vehicles

Diesel-Electric Hybrid 40-Passenger Urban Bus - The two major Canadian bus manufacturers, Orion and Novabus, are developing hybrid diesel electric power trains for urban buses. Working in collaboration with Lockheed Martin on the control systems, both companies developed prototypes, which were sent to the ETC for testing. The work done resulted in the optimisation of the control systems for the reduction of both emissions and fuel consumed by the diesel engine. These designs are now being manufactured for sale to fleets in the U.S.

Demonstration of Natural Gas Conversions of Motorcycles for the Egyptian Government Fleet - In collaboration with Industry Canada and a Canadian company, YugoTech, the ETC is providing technical expertise in the areas of exhaust emissions and testing for an international program involving converting motorcycles in the Egyptian Government fleet to natural gas. The project, funded by the federal Climate Change program, began in November 1999 with a trip to Egypt to discuss the proposal with government officials, natural gas suppliers and converters, and motorcycle manufacturers. The first 'kit' will be completed in the next fiscal year followed by exhaust emissions testing at the ETC.

6. Support to Spill Response

6.1 Summary of On- and Off-site Assistance

The following are examples of support provided by the Environmental Technology Centre (ETC) during environmental emergencies:

- advice on the properties, behaviour, fate, and environmental effects of hazardous materials using experience/knowledge and up-to-date manuals and databases;
- laboratory tests to determine physical, chemical, and ecotoxicological characteristics of hazardous materials and the effectiveness and effects of spill-treating agents;
- advice and laboratory support related to the analysis of complex, dirty samples for organic parameters and for a broad range of toxic inorganic elements;
- assistance in identifying the potential source(s) of the spill and estimating the time since the spill;
- spill-behaviour and spill-movement modelling using the latest generation models and techniques;
- advice and training related to personnel protection at pollution emergencies;
- advice and direct support related to state-of-the-art, on-site monitoring of human and environmental hazard levels at pollution emergencies;
- advice and direct support related to sample collection at spill sites;
- advice, on-site support, and airborne services for the remote sensing of spills;
- advice and on-site support involving setup and operation of equipment for sampling pollutants in ambient air;
- interpretation of ambient air quality data and assessment of impacts of pollutants measured;
- advice on and evaluation of spill countermeasures, particularly relating to containment and recovery, treatment, and disposal techniques;
- laboratory bench-scale testing and some database development to assist in the selection of oil and chemical spill cleanup technologies, e.g., to determine the effectiveness of commercially available and new oil spill sorbents;
- on-site, specialised cleanup support or technology demonstration at chemical spills and insecure hazardous waste sites through deployment of state-of-the-art prototype mobile water and soil treatment systems; and
- engineering review of possible use of various types of oil spill countermeasures or disposal equipment.

Technician testing self-contained environmental equipment

6.2 Spills/Incidents at which ETC Assisted

During the last 20 years, the ETC has provided most of the departmental technical advice, central laboratory, and on-site specialised support during response to pollution emergencies of federal interest. Pollution incidents at which the ETC provided information and advice from April 1, 1998 to March 31, 2000 are shown in Table 1. A recent example that involved measurement of hazard and contamination levels on site is the phenol and formaldehyde release near Temiscaming, Quebec. The ETC also provided the only airborne remote sensing services during the SWISSAIR 111 incident off the coast of Nova Scotia in late 1998.

Table 1 Spill Incidents at which ETC Assisted (April 1998 to March 2000)

	Date	Location	Province	Material
1998	April 8	Lachine Canal	QC	Unknown heavy oil
	June 3	Montreal	QC	Aluminum phosphide
	June 20	Point Lance beach	NFLD	Analysis of EIM samples
	August 3	Les Elevateurs de Sorel	QC	Aluminum
	August 4	Little Lawn Beach	NF	Black oil
	September 5-7	St. Margaret's Bay	NS	Swiss Air 111 disaster
	September 5-10	Swissair 111	NS	Oil, search and rescue
	September 16	St. Lawrence River	QC	Light crude
	September 23		ON	CANUSLAK - Bunker C fuel oil
	October 27	Saguenay River	QC	Fibreboard wood
1999	January 11	Montreal	QC	Wheat fire in silo
	February 5	Coos Bay	OR	New Carissa with 200,000 gal of fuel
	March 9	St. Lawrence River	QC	Unknown oil source
	March 19	Pt. Leprey	NS	Light lube oil
	March 21, 23-25, April 7	Havre St-Pierre	QC	Bulk carrier Gordon C Leetch with IFO180
	April 14	Come-by-Chance	NF	IFO 380
	April 20	St. John	NB	The Caribbean with Mobil Therm 603
	May 19	Montreal	QC	Crude oil tank explosion
	May 16-17	Temiscaming	QC	Formaldehyde/phenol
	June 2	Long-Point	QC	Chlorine
	June 10	Linton	QC	Diesel fuel
	June 18	St. Lawrence River	QC	Unknown oil source
	June 23	Beauharnois	QC	PVC fire (HCl, dioxins, VOCs, etc.)
	July 9	King's Landing	NB	Ammonium nitrate, diesel fuel, blasting caps
	July 17	Cornwallis	NS	Tire fire
	July 22	Hornepayne	QC	Diesel fuel
	July 31	Montreal	PQ	Warehouse fire - lead
	August 9	Calgary	AB	Hub oil recycling fire
	August 25	Tilson	MN	Sour gas odour
	August 27	DND site	Bosnia	Air monitoring
	August	Placentia Bay	NFLD	Water analysis at oil spill
	September 10	St. Lawrence River	QC	Unknown oil source
	September 20	South Shore Montreal	QC	Auto scrap fire
	September 21	Toronto	ON	Transformer fire
	September 21	Victoria	BC	Mystery oil spill (Bunker C?)
	September 28	Confederation Bridge	PE	Tanker truck (HCl)
	September 28	Windsor	ON	Explosion/fire (styrene, diesel, ethylene dibromide)
	September 28	Campbellton	NB	Fish kill (phenol)
	September 28	Chateauguay	QC	Industrial park fire (NH_4NO_3)
	September 30	Jasper	AB	Train derailment (gasoline, NH_4NO_3)
	November 10	Cap-Tourmente	QC	Ship run aground (clinkers)
	November 17	Oakville	ON	Refinery (MEK, hydrazine, jet fuel, Bunker C)
	November 24	Burrard Inlet	BC	Canola oil
	November 25	Montreal	QC	Water analysis at oil spill
	December 7	Vancouver	BC	Styrene
2000	January 2	St-Hilaire	QC	Train derailment (sodium chlorate)
	January 13	Vaughn	ON	Treatment plant (chromic acid)
	February 9	Port Hawksbury	NS	Gassing at dredge site (unknown gas)
	February 11	North Sydney	NS	Container truck at ferry terminal (sodium hydrosulphite)
	February 22	Montreal	QC	Nonyl alcohol
	February 15	Hungary		Cyanide
	March 3	ERMD/ETC	ON	Compare oil sources
	March 14	Fredericton	NB	Styrene, vinyl toluene, divinylbenzene
	March 17	Temagami	ON	Sulphuric acid

7. Spill Measurement, Behaviour, and Effects

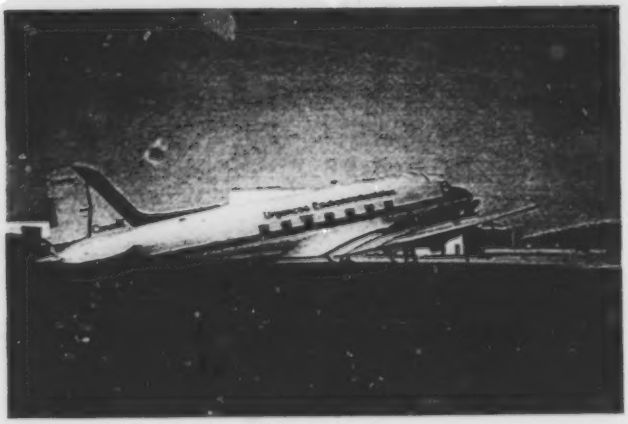
7.1 Airborne Remote Sensing Operations

The ETC owns and operates two aircraft for remote sensing. They are used primarily to develop new sensors and techniques for oil spill detection. The aircraft are also used extensively, on a full cost-recovery basis, for other applications including radar mapping of marine and terrestrial targets, radar experimentation, defence target detection, and aerial photogrammetry.

7.2 Oil Detection Using Laser Fluorosensors

Laser fluorosensors offer great potential for remote sensing of oil spills as they can positively identify oil by distinguishing it from many interferences, including vegetation and rocks with similar coloration to oil, and wind-caused 'slicks'. Such interferences have caused difficulty in detecting and mapping oil during major spills like the *Exxon Valdez*.

An older prototype unit, known as the Laser Environmental Fluorosensor, was installed in the DC-3 aircraft owned by the ETC. This unit was tested and performed well beyond expectations over several oil spills and discharge sites. Staff members constructed new electronics for the unit, which provide map-like output in real-time plus many data analysis tools. This unit was successfully used during the response to the crash of Swissair Flight 111 off the coast of Nova Scotia in September 1998.



DC-3 used for Remote Sensing

More recently, a new fluorosensor, the Scanning Laser Environmental Airborne Fluorosensor or SLEAF was installed on the DC-3 and is undergoing flight-testing. The SLEAF was designed from 1994 to 1996 and completed by early 1998 by Barringer Research and Optech of Toronto. The new unit features scanning capability (a major shortcoming with older instruments), a powerful new-generation laser (ten times more powerful), and an integrated electronic display.

The laser fluorosensor research is jointly funded by Environment Canada, the U.S. Minerals Management Service, the Environmental Innovation Program, and Transport Canada.

7.3. Airborne Oil Slick Thickness Sensor

Knowledge of slick thickness is important in order to maximise the effectiveness of oil recovery or treatment operations. A sensor has been identified with the potential to provide an absolute measurement of oil slick thickness. The sensor is known as the LURSOT (Laser Ultrasonic Remote Sensing of Oil Thickness) system. The LURSOT system employs three lasers, one of

which induces an acoustic pulse in the oil layer. The time-of-flight of the acoustic pulse in the oil, which is a function of slick thickness, is then measured remotely using laser interferometric techniques.

A full-scale mock-up of the system was successfully tested in a laboratory wave tank up to a distance of 90 m. The mock-up system was then mounted and tested in an aircraft. The unit functioned on the ground but did not function in flight. The malfunction in flight has been attributed to possible non co-linearity of the laser beams, the pickup of extraneous acoustical signals and vibrations by the detector, and temperature sensitivity of the detection laser. The mock-up unit has been re-configured to address these problems, using a newly developed photo-refractive optical ultrasonic detector (PROUD). In 2000, the new unit will be tested in flight.

The airborne oil slick thickness sensor research is jointly funded by the U.S. Minerals Management Service, Environment Canada, and Imperial Oil.

7.4 Spill Modelling

The Environmental Technology Centre (ETC) provides services, on a full cost-recovery basis, using a variety of spill models. The World Oil Spill Model (WOSM) and OilMap for Windows are used as primary tools for oil-spill modelling. While the ETC has remained active on committees dealing with the science of modelling, its own plans for continuing development and operational implementation of improved models have been stopped due to lack of resources.

7.5 Chemical Spill Analytical Projects

The ETC continues to develop analytical techniques and provide related specialised services to assist spill responders both on- and off-site. The ETC is equipped with vehicles that carry a range of person-portable and vehicle-portable equipment to ensure rapid hazard assessments at a site. Development of laboratory methodologies is ongoing, with the ultimate goal of being able to apply the improved methods on-site. Advanced sampling technologies, such as remote-controlled sampling helicopters, have also been refined and used during the reporting period. Auxiliary support vehicles were also constructed, including a prototype decontamination unit and command/communication units for supporting crews. All on-site work is now performed under full cost recovery.

The ETC maintains and continues to update reference literature on the properties, fate, and effects of over 5,000 hazardous chemicals and oils. This literature is extremely useful during spill situations and for research purposes.

7.6 Oil Properties and Analysis

Knowledge of oil properties and behaviour is essential for predicting the environmental fate and effects of oil spills and for selecting cleanup and recovery techniques and ensuring their effectiveness. New measurement techniques are being developed as well as "total analysis" techniques, which can quantify more than 350 compounds in oil. Methods were developed to analyse the bulk constituents of oil, especially waxes, resins, and asphaltenes. Studies are underway involving the correlation of dispersion, emulsification, and other important behavioural processes with the bulk components of oils.

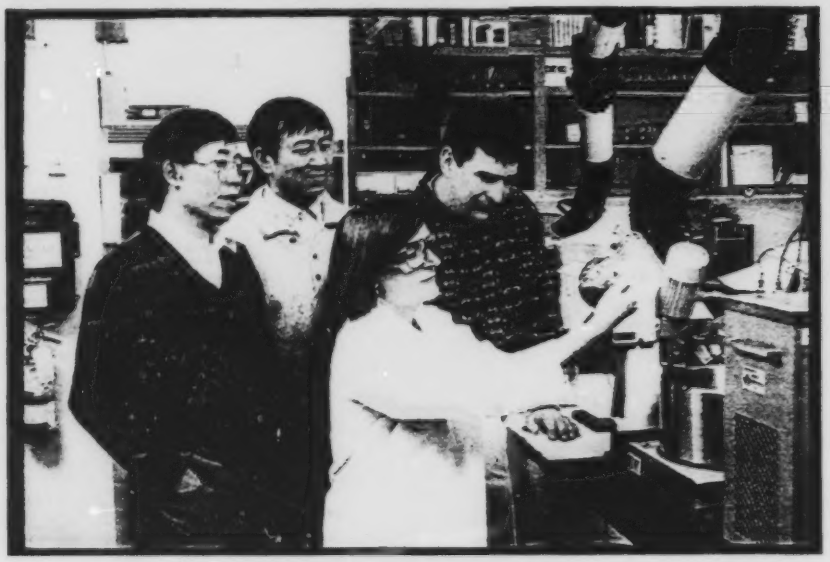
The ETC is also conducting studies to improve oil analysis for environmental purposes, such as developing a rapid means to measure solubility and new weathering and dispersibility procedures to simulate natural processes in the laboratory. The methods have been used for studying the fate and behaviour of spills and for locating unknown spill sources. From April 1998 to March 2000, seven 'mystery spills' were tracked to potential sources.

7.7 Behaviour of Spilled Oils (BOSS) Project

The BOSS project is a major program, co-funded by the U.S. Minerals Management Service, to combine all the findings of previous joint projects and literature on the behaviour of spilled oil into one source. No literature collection or review of this type now exists. Over 9,000 references have been collected and initially reviewed. Completion of the project will result in a major volume combining not only the reviews of literature, but also data tables and unpublished results. This will enable re-evaluation of processes and use of data for spill behaviour and fate modelling. From April 1998 to March 2000, the detailed review of oil-in-ice literature was completed and work was started on the review of the solubility of oil in water.

7.8 Testing of Spilled Substances/Development of Biological Methods

It is important to be able to determine the toxicity and understand the impact of substances that are spilled or likely to be released into the environment. This information affects predictions of environmental impact and the selection of cleanup response options. The ETC continues to conduct bioassay testing on a variety of chemical and petroleum hydrocarbon substances. Recently, more emphasis has been placed on the development of test procedures, so that there are reproducible and accurate means of measuring toxicity. The ETC has been an active partner in efforts to improve the use and acceptability of biological methods and data. Fifteen Reference Methods have now been produced, which provide Canadian laboratories and program managers and regulators within Environment Canada with a well-rounded array of options.



Collaboration with visiting scientists

Many substances are difficult to test owing to their low solubility or tendency to transform in water. To address one such common substance, a project began on the development of a Standard Method for preparing a water-soluble fraction from petroleum hydrocarbons for aquatic toxicity testing. The project, which has attracted international interest and participation, addresses some fundamental and overlooked issues with respect to oil behaviour.

7.9. Environmental Fate, Behaviour, and Effects of Oil

In order to select the most appropriate response option for a particular section of oiled shoreline, the operational staff and environmental advisors must make predictions about natural oil removal rates, the effects of the oil on biota, and ecological recovery rates. While subsurface intertidal oil contamination remains a significant issue and a major factor related to cleanup decisions and long-term effects, our knowledge base in this area is very weak.

To address this weakness, the ETC completed a series of bench-scale studies to investigate subsurface intertidal-zone oil behaviour, i.e., to measure the loading capacity, residual oil capacity, and permeability of sediments of different grain sizes using various types of oil with different properties. This project was extended by scaling it up to a mesocosm laboratory and finally to a real test of oiled rocks on location in a cove on Vancouver Island. A second project has been the acquisition, review, selective extraction, and consolidation of tens of thousands of records of oil-on-shoreline data collected from monitoring programs in Prince William Sound, Alaska conducted during U.S. Government and EXXON surveys following the *Exxon Valdez* oil spill and from the *Nestucca* spill off British Columbia. A third initiative has been the development of a comprehensive model to predict oil removal rates from marine shorelines and the incorporation of all this data into new shoreline cleanup manuals.

7.10 Post-spill Monitoring

Post-spill monitoring may be conducted to evaluate the effectiveness of cleanup actions/decisions that were taken and to verify and refine predictions of longer-term oil fate, behaviour, effects, and rates of biological recovery. Two surveys were conducted during the review period that focused on the natural removal rates of oil on shorelines. In 1998, a systematic survey was conducted of the *Arrow* spill site in Nova Scotia. The spill occurred in 1970. Some of the treatment technologies on this particular spill did not work well and areas on some beaches remain coated with oil to this day. These results continue to advance our understanding of the long-term behaviour of oil in these environments and to determine the best countermeasures for such spills.

8. Spill Countermeasures R&D

8.1 *In-situ* Burning

Several recent large oil spills have re-confirmed that oil contamination of shorelines causes extensive environmental damage and results in very high cleanup costs. Analysis of the *Exxon Valdez* oil spill indicated that perhaps more than half of the spilled oil could have been burned *in-situ* without igniting the oil remaining in the vessel, thereby significantly reducing shoreline contamination.

Intensive laboratory and tank testing on the *in-situ* combustion of oil indicated that the nature and concentrations of atmospheric emissions from *in-situ* burning of oil offshore would sometimes be preferable when weighed against the environmental damage and cleanup costs of nearshore and shoreline contamination. Studies on the emissions of *in-situ* burns continued. A series of meso-scale burns was conducted in Mobile, Alabama in 1998. The ETC joined with the U.S. EPA in establishing an extensive monitoring program for emissions. Data analysis continues.

Meso-scale burn, Mobile, Alabama

Data analysis also continued on several extensive burn studies conducted in the past. These studies show that combustion gases including carbon dioxide, sulphur dioxide, and carbon monoxide did not reach levels of high concern. These gases were emitted over a broad area around the fire and were not directly associated with the plume trajectory. Volatile organic compounds (VOCs) were abundant, but at lower levels than those emitted from an equivalent non-burning spill. Over 140 compounds were quantified, several at levels near human health exposure maximums up to 100 m downwind.

Water under the burns was analysed for volatile compounds. No compounds were found at the detection level of the methods employed.

Airborne particulate material, the starting oil, and subsequent burn residues were analysed for metals. Metals were not detected on the airborne particulate material - other than small amounts derived from the fire-resistant boom used to contain and thicken the slick. Slightly elevated metal concentrations, above that noted in the starting oil, were found in the residue, indicating that metals are largely deposited in the burn residue, rather than released in the smoke and soot particles.

Polycyclic aromatic hydrocarbons (PAHs) were found at lower concentrations in the soot than in the starting oil and were consumed by the fire to a large degree. Particulate matter in the air was measured by several means and found to be of concern only up to 150 m downwind at sea level.

8.2 Chemical Spill-treating Agents

Since treatment of oil or chemical spills involves applying additional chemicals to the environment, it is essential that adequate information is available about the toxicity and effectiveness of these chemicals. The ETC is developing and implementing tests for this purpose. Performance tests will ultimately be developed for 12 classes of chemical spill-treating agents. So far, tests have been developed for dispersants, solidifiers, surface-washing agents, and biodegradation agents. Over 100 agents from these four classes have been tested in recent years. Tests have also been developed for emulsion breakers, recovery enhancers, and emulsion preventers. Work is continuing on the testing of new agents.

The chemistry and physics of dispersants are being studied, especially stability over periods approaching days and particle size. In addition, work is continuing on the development of test methods for evaluating dispersants. One of the methods developed at ETC is now an American Society for Testing and Materials (ASTM) standard.

This work is jointly funded by Environment Canada and the U.S. Minerals Management Service.

8.3 Evaluation of Sorbents

The ETC has led a project to develop an improved performance standard for testing oil spill sorbents. A Canadian General Standards Board (CGSB) testing protocol was previously developed, which targets performance parameters for sorbents used to combat oil spills. Additional work was done to ensure that compatible testing protocols were developed in the U.S. A standard ASTM testing protocol has subsequently been developed and ratified. Results to date have been tabulated in a database that is being made available by June 2000 as a publicly accessible resource on the Internet.

Testing recovery equipment for spills of Orimulsion(TM) at EETO

A similar test program is also ongoing, targeting sorbents suitable for use on chemical spills. Sorbent performance, compatibility, and solubility are primary parameters to be assessed, using a range of 'aggressive' test liquids. The results of these tests will be used to support the development of new ASTM protocols.

8.4 Evaluation of Mechanical Containment and Recovery Equipment

In collaboration with the Canadian Coast Guard, the product vendor Bitor America, and some equipment suppliers, the ETC and SAIC have recently tank-tested some specialised

countermeasures equipment for Orimulsion™ spills. A device designed to accelerate the reflotation of bitumen was tested in both fresh and salt water to assess its effectiveness and the influence on bulk water concentrations of bitumen over time. Several candidate skimmers were also tested at the same time to determine their capacity to collect and process the viscous bitumen product.

8.4.1 Countermeasures Study as a Contribution to Sound Contingency Planning Decisions

In 1998, an ETC-sponsored report on the Countermeasures Study entitled "Self-help Spill Countermeasures for Oil Tankers" was sent by the study's major co-funder (the U.S. Coast Guard – USCG) to the United States Congress as part of an earlier Congress-imposed legal obligation by the U.S. government to report to Congress on this topic. The study is also relevant to Canadian marine oil spill contingency planning. Based on the study, the USCG concluded that the practical limitations of such countermeasures make it undesirable/unfeasible to require that oil tankers carry such 'self-help' equipment.

8.5 Development of Standards

Since 1991, the ETC has been involved in a program of standards development for oil spill cleanup in partnership with agencies such as the U.S. Coast Guard, which is responsible for administering the *Oil Pollution Act, 1990* (*OPA 90*), and other research and industrial groups concerned with technologies for responding to marine oil spills. Standards, Guidelines, and Protocols continue to be developed through the applicable American Society for Testing and Materials (ASTM) F-20 sub-committee to ensure compatible standards for North America. The ETC is also participating in developing standards for areas such as sorbents, remote sensing, dispersants, communications, and in-situ burning.

SAIC Canada, formerly the Emergencies Engineering Division of the ETC, has continued to contribute to the modification of protocols for the performance-based evaluation of chemical spill cleanup equipment ("mitigation") for treatment of surface waters and groundwaters within the ASTM forum. Separate guides address such equipment as membrane technologies, advanced oxidation units, and steam-stripping processes. The existing ASTM "Guide for Developing a Hazardous Materials Training Curriculum for Initial Response Personnel" is being significantly revised by SAIC staff within ASTM Subcommittee F20.2100 on "Initial Response Actions". Revisions also continue within this group on ASTM Guides for Health and Safety Training of Oil Spill Responders.

9. International Transfer of Canadian Technology

9.1 Australia

A staff member visited two state environmental agencies in New South Wales and Victoria as well as Environment Australia. Information was exchanged on an air pollution measurement network and techniques as well as pollution levels and objectives. A staff member was also invited to train staff at the Australian Government Laboratories near Sydney, NSW in dioxin analysis techniques. A complicated PCB sample was also analysed for the same laboratory.

9.2 Brazil

As part of the CIDA-funded Watershed 2000 management project for the State of Sao Paolo, an ETC staff member reviewed the training for laboratory accreditation. Several laboratory audits were also conducted in preparation for site visits by INMETRO, the Brazilian accreditation agency.

9.3 Chile

Several sets of samples have been shipped to the CENMA laboratory in Santiago, Chile to provide external validation of their analytical measurements for air pollution. A staff member participated in an audit of the analytical laboratories and a national seminar on quality assurance for environmental laboratories held at the same location.

9.4 India

A diagnostic visit was made to the Ministry of Environment and Forest in India to develop a proposal to provide technical assistance with air pollution monitoring under the CIDA-funded Canada-India co-operation program.

9.5 Hong Kong

A scientist from the Analysis and Air Quality Division provided advice, training, and inter-laboratory comparison of VOC analysis to the Hong Kong government's Environmental Protection laboratory. At the laboratory's request, visits were made to the facility for on-site training and equipment setup in February 1998 and January 1999.

9.6 Mexico

As part of a project to assess the impact of air pollution on human health in Mexico City, a staff member visited the National Ecological Institute, part of SEMERNAP, the national environmental agency. Analytical techniques and the results obtained were reviewed.

9.7 Pakistan

Two staff members conducted a seminar on quality assurance in Islamabad, Pakistan as part of a CIDA-funded project. The seminar provided technical assistance as part of a new regulation requiring self-reporting by polluting industries.

9.8 Poland

In conjunction with Warsaw University in Poland, a capillary electrophoresis (CE) method is being developed with laser-induced fluorescence (LIF) detection for the determination of dimethylamine (DMA) and other low-molecular-mass amines involving pre-column derivatization with fluorescein isothiocyanate isomer I (FITC). The proposed CE-LIF method appears to be an attractive choice for the determination or confirmation of dimethylamine and other low-molecular-mass amines in atmospheric aerosols and other environmental samples. As part of this project, a seminar on CE was presented at Warsaw University in March 2000.

9.9 Netherlands

Co-operative research into inorganic analytical methods continued with RIVM, the Netherlands Institute for the Environment and Public Health. A researcher from RIVM visited ETC in May 1998 and in exchange two ETC staff visited RIVM in February 2000 where they gave presentations on the NAPS network and capillary electrophoresis.

9.10 U.S.

A joint U.S. Environmental Protection Agency/Environment Canada Committee on analytical methods meets once a year, usually during the Pittsburgh Conference, to exchange information and progress. It also examines possibilities for undertaking co-operative development of analytical methods. A manager from ETC's Analysis and Air Quality Division (AAQD) acts as the Canadian co-chair.

An AAQD scientist was appointed to a U.S. EPA-sponsored peer review panel for the Particulate Matter Research Centre program ($40M over 5 years) and attended the panel meeting in Washington in February 1999. This scientist was also appointed to a second EPA-sponsored peer review panel for the Particulate Matter Supersite program ($20M over 5 years) and attended the panel meeting in Washington in September 1999.

9.11 Ukraine

9.11.1 Rationale and Goal

Since 1995, as part of Canada's support for Ukraine acceding to the international nuclear 'Non-Proliferation Treaty', the ETC has been helping to transfer Canadian techniques and equipment to be used for environmental assessment and remediation of the chemical contamination at Inter-Continental Ballistic Missile (ICBM) sites. The rationale and goals of this Environmental Assessment and Remediation Program (EARP) are detailed in the "1994/1996 ETC Biennial Report".

9.11.2 Training Program

Under the most recent phase of the EARP, 14 remediation engineers and scientists from the Ukrainian Ministry of Defence, the Academy of Science, and the Ministry of Environmental Protection were trained in Canada for a six-month period ending in July 1997.

The first part of the formal training covered environmental assessment and remediation topics such as: workplace hazardous materials information; laboratory safety; steps for environmental site assessment; field and laboratory analytical methods; personal protective equipment and clothing; environmental philosophy; environmental regulations and criteria; identifying, classifying, and assessing sites; geophysical investigation techniques; drilling and installing monitoring wells; sample collection, logging, and analysis; quality assurance/quality control; risk assessment; choosing/implementing technologies; health and safety; public and community relations; site closure; and long-term monitoring.

The second part of the training covered the philosophy of doing business in Canada with topic areas such as: English language training; computers, finances, and accountability; time management; and project management.

Additional, more informal training covered topics such as: tours of companies, centres, and universities; analysis of soil and water samples and demonstration of lab analytical instruments; technical workshops on specific topics; evaluation of technical project proposals; self-directed study and practice of skills; and field work and preparation of a technical report for Canadian Forces Base, CFB North Bay.

10. Technologies for Decontaminating Water

10.1 Electrochemical Treatment of Acid Mine Drainage an d Potential Applications to Site Remediation

Engineer at work

In support of several Canadian Universities in Educational Development, a number of collaborative projects have been undertaken with Chemical Engineering faculties over the past few years. One example is a joint study by SAIC and Guelph University of Electrochemical Treatment of Acid Mine Drainage (AMD), with the view to other potential applications for sites contaminated with heavy metals. Although the resulting technology could assist in reducing the widespread problem of AMD, SAIC and EETO/EC's interests are more confined to the technology as a tool for the cleanup of heavy metals in contaminated groundwaters.

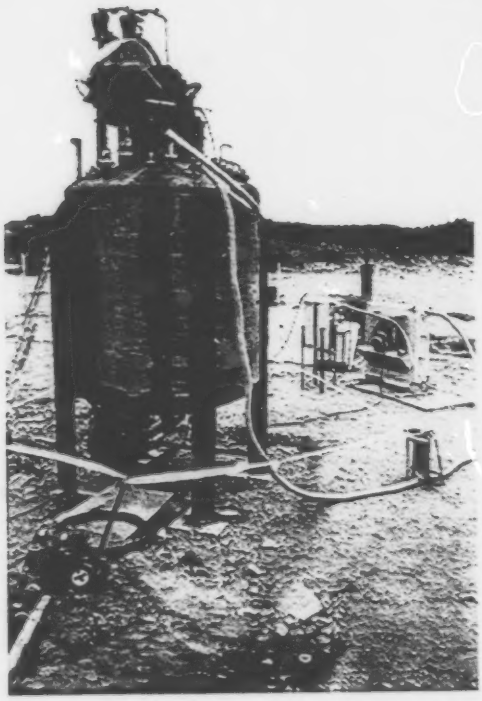
The study involved processing synthetic AMD fluid through a membrane for anion exchange, with varied pH, flow rate, and electrical current. By selective design, efficiencies of up to 99% were achieved, along with fewer chemical additives, less heavy metal precipitation outside the cell compartment, and easier neutralization. The demonstration of copper recovery showed that the technology has potential for application to sites contaminated with heavy metals. Further work on this problem is planned at Guelph. Funding from other sources will be needed in the future.

11. Technologies for Decontaminating Soil

11.1 Potential Remediation of Sediments from Tar Ponds

Under a major project, SAIC has studied a range of bench-scale technologies for potential applications to heavily contaminated sites such as the Sydney Tar Ponds (STP) area in Nova Scotia. These types of sites contain a wide range of toxic contaminants, both organic and inorganic, in a complex soil and sediment matrix. Among the processes tested were soil washing, enhanced washing, chemical leaching, and the Microwave-Assisted Process (MAP™). Supercritical fluid extraction, an Organic Destruction Process (formerly called "SIAL") supplemented by advanced oxidation and Microwave-Activated Cracking were also evaluated. The concept of coupling the MAP™ process with a two-phase partitioning bioreactor was also reviewed. Although complications related to STP soil heterogeneity and complex sample analysis were anticipated and encountered, this work will continue as a potential technological contribution toward solving a challenging pollution problem in Canada.

11.2 Destruction of Chlorinated Organic Compounds in Soil



Field testing of organic destruction process reactor

With support funding from the Industrial Research Assistance Program (IRAP), Environment Canada/ETC identified the cleanup of chlorinated toxins in soil as a priority area for R&D. The objective of the project was to further develop a solventless, non-incineration process for treating soils contaminated with chlorinated organic compounds such as polychlorinated biphenyls (PCBs), pentachlorophenols (PCPs), dioxins, furans, and pesticides. A process train, including the Organic Destruction Process, with supplementary advanced oxidation treatment was assessed in both a lab (bench-scale) and field environment. It was concluded that further bench-scale testing and design modifications are required to optimise the operating parameters before this technology is viable as a full-scale treatment process.

11.3 Two-phase Partitioning Bioreactor for Soil Remediation

A combination of biological and chemical processes is featured in a new technology first developed by researchers at Queen's University in Kingston, Ontario. Subsequent joint work at ETC and Queen's by SAIC and Queen's researchers respectively, shows considerable promise for this

continuous process technology in the treatment of soils with mixed contamination of organic and inorganic substances such as hydrocarbons and heavy metals. The process combines pre-treatment by solvent extraction with microbial treatment at a self-adjusting optimum feed rate. Preliminary results show that this technology might compete favourably with incineration and low-temperature thermal desorption under a wide variety of conditions. It may also compete with slurry-phase bioreactors, especially for soils with a high concentration of contamination, and with solvent extraction, particularly if the cost of disposing of the final concentrated stream is taken into account. Further studies are planned.

12. Advancement of Science and Technology

12.1 Good Laboratory Practice (GLP)

The Good Laboratory Practice (GLP) *Compliance Monitoring Unit* is responsible for developing a GLP program in support of the New Substances Notification Regulations (NSNR) of *CEPA*. During the past two years, the ETC completed two GLP inspections and one pre-inspection of domestic testing facilities. Two other inspections were conducted jointly overseas with monitoring authorities from other member countries of the Organisation for Economic Co-operation and Development (OECD). These inspections were done as part of a larger OECD initiative that involves mutual joint visits (MJVs) to compliance monitoring agencies in other countries in order to gain confidence and information on each other's procedures. It is expected that representatives of three other OECD countries will review the Canadian monitoring program in May of 2000. In turn, Canada is scheduled to participate in three other such joint visits later in the year.

As well as providing inspectors for the MJV program, the ETC has continued to represent Canada on the OECD GLP Panel (recently renamed the Working Group on GLP). ETC staff have also served on the Steering Group that is administering the program and reviewing its results. The ETC and other Environment Canada and Health Canada employees participated in a biennial OECD GLP inspector training course, held in Italy in 1999. Staff of the Compliance Monitoring Unit have served as auditors for the Canadian Association of Environmental Analytical Laboratories (CAEAL) in the Standards Council of Canada (SCC)/CAEAL laboratory accreditation program. The staff of this unit have also assisted the ETC laboratories in maintaining their SCC/CAEAL accreditation.

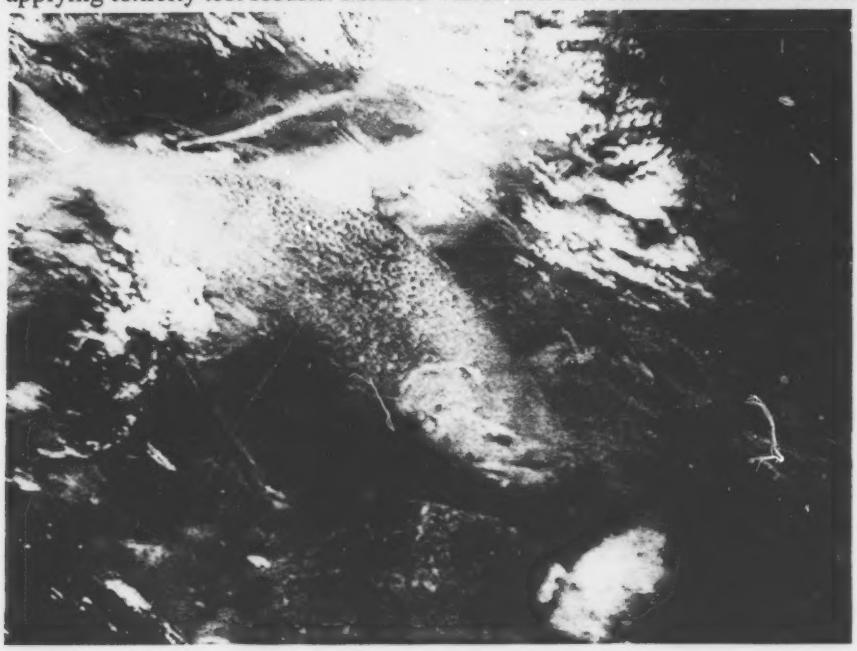
The ETC's database for storage and retrieval of information on the GLP inspection activities of OECD member countries has now been adopted as an OECD project. The ETC provides the lead for the Steering Group charged with overseeing this work. Read-only versions of the database have been provided to OECD member countries for the past two years. Presentations on using the database have been made at meetings of the GLP Working Group and at a training course for Italian GLP inspectors in 1998.

The Unit has continued to provide GLP information and support to Health Canada's Pest Management Regulatory Agency and the Environmental Health Directorate. Co-operation and planning with the New Substances Notification Regulations program has continued, most recently with assistance in designing a tracking system for use by evaluators of New Substances and in public consultation on the revision of the NSNR during the next year or two.

Activities on the negotiation of international agreements that mutually recognise the equivalence of GLP compliance monitoring programs have continued during the reporting period, although on a diminished scale. Such agreements pave the way for the mutual recognition of testing data on new substances - a cornerstone of the OECD Chemicals Program. They lead to reduced regulatory trade barriers and international costs associated with health and safety testing of new substances. Negotiations are continuing with the European Union, the three European Union Free Trade Association countries (Switzerland, Australia, and New Zealand), and may soon begin with Japan.

12.2 Method Development and Application

During the two years under review, ETC staff have balanced test method standardisation activities with a growing demand from other departmental staff for assistance in interpreting and applying toxicity test results. Method validation and standardisation efforts have focused primarily on: 1) marine sediment tests required by the *CEPA* Ocean Disposal program and 2) standardisation of a rainbow trout early-life stage test and an aquatic plant growth inhibition test required for the Environmental Monitoring component of the Pulp and Paper and Metal Mining Effluent Regulations. Three new test method documents outlining standard procedures for assessing the effects of contaminated sediment on benthic amphipods and toxicity of water-borne contaminants on fish and aquatic plants were prepared and distributed in support of these departmental programs.



King Salmon in spawning grounds

ETC staff have also provided advice to several other Environment Canada programs, e.g., toxicity compliance provisions of the Pulp and Paper Regulations of the *Fisheries Act*; expert witness services for Ontario Region Inspections Division; sublethal toxicity testing requirements and data interpretation under the Pulp and Paper Environmental Effects Monitoring (EEM) program; ocean dumping monitoring program; acute lethality and EEM sublethal toxicity needs for the upcoming amendment of the *CEPA* Metal Mining Liquid Effluent Regulations (MMLER); and completeness of toxicity test data submitted under the *CEPA* New Substances Notification Regulations. To aid these programs, the ETC initiated a guidance manual on interpreting and applying environmental toxicology data. Following considerable internal and external review, the guidance manual will be published and distributed in April 2000.

In addition, the ETC staff have been involved in implementing the toxicology component of the CAEAL laboratory accreditation program. Since CAEAL has limited toxicology expertise, the program relied heavily on Environment Canada staff. For example, ETC staff prepared test-specific checklists for 18 acute and sublethal toxicity tests for use by CAEAL auditors during the 1998 and 1999 laboratory inspections; held an auditor training session in February 1998 with the

assistance of staff from the EC Pacific Environmental Sciences Centre in North Vancouver, which was attended by all CAEAL toxicology auditors; and participated in five toxicology laboratory inspections as volunteer auditors to CAEAL in 1998 and 1999.

Methods for Fuels

The Analysis and Air Quality Division is represented on the Petroleum Test Method Committee of the Canadian General Standards Boards (CGSB) and the Canada Fuels Exchange management committee. The CGSB methods for Lead in Gasoline, Sulphur in Diesel, and the Method for Individual Components in Gasoline by Gas Chromatography were reviewed for reissue.

Sampling Guidance for PCBs

As PCBs are found in materials other than transformer oils, a guidance method was developed for sampling of PCBs in ballasts, building debris, liquid paint, and automotive shredder residue. This sampling document links into the previously published PCB analytical reference method and will be useful for applying the *CEPA* PCB regulations.

Guidance Document for Metal Mining Effluents

With the aid of a consultant, a Guidance Document has been produced for the revised Metal Mining Effluent Regulations. This document uses the performance-based approach by setting criteria for detection limits, precision, and quality assurance requirements. Reporters of information to Environment Canada are free to choose their own analytical method as long as the criteria are satisfied.

12.3 Environmental Management System (EMS)

Speckled Trout Creek in Northern Ontario

During the two years under review, work continued on the design and implementation of an Environmental Management System (EMS) for the Centre using the ISO 14000 model. Key activities included the following.

- Despite some realignments of the Corporate EMS program, the ETC continued to participate in Corporate EMS working groups, providing expert advice and support in the areas of transportation, solid waste, and ozone-deleting substances (ODS). In the fall of 1999, the Department combined many of the 23

aspects into a more manageable number of 13. The Centre's ODS plan was chosen as the model for developing EMS documents for all these 13 departmental aspects. ETC staff also provided technical support to the Environmental Protection Service's EMS planning which is co-ordinated through ETAD headquarters.

- Through a contract, work was initiated to re-examine ETC's Initial Environmental Review (IER) document in order to align it with the new reporting and implementation priorities being developed by the Corporate EMS team. Hazardous wastes are the next priority for ETC and work has begun to develop a Management Strategy and Action Plan for this aspect.

- The Federal Programs Division (FPD) of Ontario Region produces videos aimed at preventing pollution in various industry sectors. ETC entered into a joint project with Ontario Region to develop a video for laboratory operations. The 20-minute video, "Pollution Prevention in Laboratories", highlights the many greening activities in place at ETC, which other laboratories can consider for their operations. It has been widely distributed, both nationally and internationally and is available free of charge to interested parties [contact Mike Bumbaco, ETC (613) 991-2387 or Ron Nobes, FPD (613) 952-8994].

- As a result of the promulgation of the new Federal Halocarbon Regulation (FHR) in June 1999, there was some urgency to update ETC's existing ODS Management Plan to reflect the requirements of this new regulation. A contractor was hired and an updated plan was completed in February 2000. As the new regulations require significant reporting, work was begun on a new ETC Halocarbon electronic database to track inventory and generate reports.

- In March 2000, the ETC once again served as a pilot facility for the Ontario Region's Federal Programs Division. The Division undertook a detailed three-day, on-site audit to determine ETC's compliance status with the new Federal Halocarbon Regulation. The purpose was to evaluate and fine-tune their audit protocols since the Division intend to offer this auditing service to other federal government departments and agencies. It allowed the ETC to ensure that the new FHR management plan is comprehensive and complete.

12.4 Quality Assurance/Quality Control (QA/QC)

The development and implementation of the QA/QC system for ETC's analytical chemistry operations and subsequent accreditation through the Standards Council of Canada/Canadian Association of Environmental Analytical Laboratories (SCC/CAEAL) proceeded very well. Through the Implementation Committee, chaired by an ETC QA Officer and made up of technical representatives from all Divisions with analytical operations, the following major tasks were accomplished.

- A Centre–wide Quality Manual and related documentation were developed and changes to them are co-ordinated through the QA Officer.

- A total of 35 test procedures and 101 standard operating procedures (SOPs) were developed and documented for inclusion in the scope of the SCC/CAEAL accreditation.

- ETC's analytical laboratories enrolled in CAEAL proficiency testing round-robins for 8 parameters measured routinely in their operations including PAH in water, PAH in soil, PCBs in oil, major ions on air filters, pH in water, PCBs in water, Microtox IC50 in water, and BTEX/THM in water.

- Training sessions were held to inform all ETC staff of the QA/QC system. A training/orientation program was put in place to explain the system to all new staff.

- A shared drive on the ETC LAN was set up as a readily available repository of Lab QA documents. Included are lists of current authorized test methods, draft test methods, all current SOPs, laboratory equipment, approved suppliers, certified reference materials, and CAEAL proficiency testing results.

- In September 1999, the Centre's quality management system was audited by SCC/CAEAL and, following responses to the audit findings, Centre-wide accreditation was achieved in January 2000. This means that ETC's analytical quality systems are recognized as meeting the Canadian National standard (CAN/CSA-Z753) and the International standard (ISO Guide 25) for data generated in its analytical operations.

- The Analysis and Air Quality Division (AAQD) at the ETC participated in a fourth international dioxin study. This study, conducted by UMEÅ University in Sweden, allows participants to judge their performance against 58 other dioxin laboratories worldwide. Four other Canadian laboratories also participated. Each lab was required to analyse samples of soil, sediment, and sludge for chlorinated dioxins and furans. In addition, labs were asked to report all co-planar (dioxin-like) PCBs. While there is no formal ranking of labs, the ETC results were very close to the overall mean for all parameters reported - indicating excellent overall data quality.

- ETC staff also participated in the fifth International Calibration Study conducted by UMEÅ University on chlorinated dioxins and furans, mono-ortho, and planar PCBs in fly ashes and in MOE's 99-02 International Study on co-planar PCBs, chlorinated dioxins and furans in sediments. Results of these studies are pending.

- The AAQD laboratory participated in 3 studies from the Canada Fuels Exchange program for sulphur and benzene in gasoline. A staff member continued to provide technical advice to the Canadian Association of Environmental Analytical Laboratories as Chair of the Program Committee.

13. Commercialisation of Environment Canada's Patented Microwave-Assisted Processes (MAP™)

MAP ™ pilot plant

13.1 What is MAP?

The Microwave-Assisted Processes are a series of inventions that support sustainable development, as they require less energy and solvent than conventional processes, while generating less waste. Furthermore, in some applications, the processes have shown potential for valorising biomass that would otherwise be regarded as a waste product. To date, ten MAP patents cover six distinct fundamental inventions with applications in a large number of areas. Two of the disclosures cannot be revealed at this time as they are still protected under the *Patents Act*.

The other four inventions can be described as: i) the modification, using microwaves, of the physical micro-structure of a variety of complex matrices, e.g., to rupture cells; ii) the selective heating of one component of a complex system, e.g., to heat a soil over the solvent being used to remove pollutants; iii) the application of microwave energy selectively to one phase over another one, e.g., water over steam; and iv) the alteration of the distribution of chemical species under given temperature and pressure conditions, e.g., to vaporise volatile organic compounds preferentially over water for their quantitative determination.

The MAP technologies use microwaves and solvents that are relatively transparent to microwaves to extract chemicals from various matrices. The applications of the technologies include a rapid sample preparation method for the analytical laboratory and a cost-effective replacement for conventional industrial extraction processes. Compared to conventional extraction and sample preparation methods, the MAP techniques reduce the production time, energy, solvent consumption, and waste generation, while increasing extraction yields and extract purity. These advantages not only reduce operating costs, but also result in a more environmentally friendly process.

Environment Canada, which owns the intellectual property rights for this technology in several countries, is investigating further applications of the technology to solve a number of environmental problems, such as the remediation of contaminated sites. The research and development of these techniques are performed in collaboration with the private, public, and academic sectors.

13.2 Licensing of the Various Applications of the MAP Technology

To effectively promote and implement the commercialisation of the MAP applications and to provide technical support to end-users, Environment Canada has nine licensees. Le Centre de développement Pronatex, inc. of Sherbrooke, Québec has rights in the areas of large-scale industrial applications of the technology. The CEM Corporation of Matthews, North Carolina, la Société PROLABO of Paris, France, and the Hewlett-Packard Company of Wilmington, Delaware, have rights in the various fields of activities that require analytical capability such as chemistry, environmental sciences, food science, forensic science, and cosmetics. The French firm, SAIREM from Lyon, France has rights for the support of large-scale industrial applications.

In the last two years, four more licenses have been granted for MAP applications to Shimadzu Corporation of Japan, CanAmera Foods, SAIC Canada, and BC Research. Shimadzu Corporation is a world leader in innovative laboratory analytical instruments and holds the rights to internationally manufacture and market equipment using gas-phase extraction technology, a patented technology within the portfolio of the MAP family of technologies. CanAmera Foods is Canada's largest processor of canola seeds and has rights to use MAP in the industrial processing of selected oilseeds. This agreement is the first aimed specifically at industrial-scale processing. SAIC Canada has rights to use MAP for certain environmental applications. BC Research Inc. has certain rights to the MAP technology with the aim of providing the industrial sector with a Canadian-based source of technical support. The ETC works closely with licensees and groups interested in developing and custom-tailoring new applications of MAP.

13.3 Enhancement of International Exposure of the MAP Technology

Technology transfer activities have resulted in numerous presentations, meetings, workshops, and training sessions on the MAP technology in Asia, Europe, South America, and North America. Such international exposure has led to various collaborative and joint project agreements, some of which are described here.

MAP international activities also involve the on-site training of interested parties. Research scientists as well as industry representatives from around the world, including the U.S., Spain, Korea, Venezuela, China, and Colombia, have come to the ETC to be trained in the use of MAP for various applications. These parties have worked on-site for periods of three to six months. The MAP Division regularly hosts scientists from academia and industry and trains them on-site on their specific applications for the MAP.

13.4 MAP™ Centre of Excellence

In January 1996, a formal agreement was signed between the Environmental Technology Centre, the Chinese Research Academy of Environmental Sciences (CRAES) of China's National Environmental Protection Agency, and China's Nankai University to work jointly to provide China with expertise and equipment related to Environment Canada's patented Microwave-Assisted Process (MAP™). This agreement was established under the auspices of the 1993 China-Canada Memorandum of Understanding on Environmental Co-operation.

The MAP technology has many applications including: preparation of analytical samples, extraction of natural products from plant material, and the removal of contaminants from soil. The Chinese partners were particularly interested in the contaminated soil applications for the cleanup of China's many contaminated sites and in introducing this clean/environmentally friendly process to China's natural product industry. Therefore, with partial financial support from Environment Canada's International Partnership Program, one MAP pilot-plant and two analytical MAP apparatus were sent to CRAES and to Nankai University, respectively. ETC staff trained Chinese researchers on the use of this equipment. An ETC staff member was on site at CRAES for 3 months to oversee and help set up the facilities. In January 1998, Environment Minister Jane Stewart officially inaugurated the MAP Pilot-plant facilities in Beijing.

In 1997, funding was approved under CIDA's China-Canada Higher Education Program for a five-year joint project between Environment Canada (ETC), McGill University, Nankai University, and CRAES to provide Chinese researchers with training related to microwave-assisted processing including some specific MAP applications. The project is valued at $1.8 million over its 5 years. As part of this project, four Chinese candidates will pursue MSc and PhD degrees at McGill University and will be granted full-time academic positions at Nankai University upon their return to China. At least 10 other Nankai University and CRAES staff will come to Canada for short-term training visits. All aspects of the training are being carried out jointly by ETC and McGill, using both their facilities. As well, during the course of the project, a microwave-assisted processing curriculum is being developed for implementation by Nankai academic staff at Nankai by the end of this project.

In 1998, Professor J.R.J. Paré, Chief of the Microwave-Assisted Processes Division at ETC, was named Visiting Professor by Nankai University, with full teaching privileges and rights in recognition of his contribution to the development of Nankai's capacity. Similarly, the Kunming University of Science and Technology bestowed upon him the title of Honorary Professor for his outstanding contribution to China's development in the area of microwave chemistry.

From 1996 to 1999, staff at ETC and McGill gave formal technical lectures to potential or actual collaborators of CRAES and Nankai at a number of sites in China (Beijing, Tianjin, Shanghai, and Kunming). To date, more than 600 participants attended this series of formal "training" lectures aimed at the Chinese industry. This collaboration will create a cadre of scientists in China who will be able to support the further development and commercialisation of this "green" Canadian technology in China. Their expertise will relate to both industrial uses of the technology as a "clean industrial-scale" process and its use in analytical chemistry laboratories as a "green" sample preparation method.

In May 2000, Environment Canada, with its Canadian (McGill) and Chinese (Nankai and CRAES) partners is holding the first International Symposium on Microwave Chemistry in conjunction with the Third Chinese Symposium on Microwaves. Under the theme: "Microwave 2000: Sustainable Technologies for the New Millennium", the symposium will be held in Tianjin and will be the first such meeting to be held worldwide.

14. Development of MAP Analytical Methods and Instrumentation

The MAP technologies have applications in the liquid and gas phases, as well as in sub- and super-critical fluid conditions. Some typical examples of the use of MAP in the liquid-phase are: extraction of essential oils, aromas, and flavours from plant material; extraction of polycyclic aromatic hydrocarbons (PAHs) from polyurethane foams (PUFs) used in air monitoring; extraction of polycyclic biphenyls (PCBs) from animal tissues; and the extraction of a variety of analytes from solid materials, including soils and sediments. Other examples of applications include the extraction of oil from oil-seeds, the remediation of contaminated sites, and the extraction of valuable products form biomass that would otherwise be regarded as waste products. Due to its environmental advantages, the process has been awarded an Eco-Logo™ under the Environmental Choice Program.

Scientist using MAP (TM) technologies

14.1 Official MAP Methods

In 1996, Environment Canada released the first Reference Method for PCBs in oil that specifically includes the MAP technology. Another example of the ability of MAP to contribute to pollution prevention is the approval by the U.S. Environmental Protection Agency of a MAP method (SW-846 Methods of the Office of Solid Waste 3546) for use as a Standard Reference Method for preparing environmental analytical samples. This is also an approved CEPA regulatory Reference Method.

The introduction of these methods to laboratories is significant because it is estimated that about 100,000,000 L of organic solvents are used in organic analytical laboratories worldwide each year. The MAP method requires about 90% less solvent than is used in conventional Soxhlet methods of sample preparation. Consequently, the waste produced by the procedure is reduced significantly. Furthermore, toxic solvents, such as dichloromethane, currently used in conventional methods, can be completely avoided – thus greatly reducing human exposure to this substance. In most cases, energy requirements are also reduced by about 99%, which translates into a significant reduction in greenhouse gas emissions. This is the first time that the U.S. EPA and Environment Canada have put a joint national Reference Method in place. The method can be used for the determination of over 100 pollutants from various sample matrix, such as soil, water, and animal tissues.

Environment Canada and the U.S. EPA are evaluating other applications of MAP as part of a Joint Project Agreement signed under a Memorandum of Understanding for Science and Technology. This agreement covers activities related to hazard-level monitoring for emergency response and site assessments, including methods for PCB in oil, PAH and PCB in soil and in air filter media, and chlorinated dioxins and furans in soil.

Sediment from the Great Lakes is being certified as a Standard Reference Material for dioxins through a round-robin evaluation that is using a MAP method as the sample preparation step. Similar activities are proceeding at the National Institute of Science and Technology (NIST) in the U.S.

Other agencies dealing with the quality and efficiency of good laboratory practices in various fields are also reviewing the use of MAP methods as standards. These agencies include the American Society for Testing Materials (ASTM), the Orange County Coroner's Department, the U.S. Department of Agriculture, Associations of Official Analytical Chemists, and Agriculture and Agri-Food Canada.

The co-ordinator of the Association of Official Analytical Chemists (AOAC) for France is seeking the development of two official methods, one for the determination of fat in meat and meat products and another for the determination of fat in dairy products. These methods developed by the ETC are currently undergoing the first stage of the stringent review process associated with AOAC methods.

14.2 MAP Water Quality Measurement Technologies

MAP work is progressing in the development of rapid and quantitative protocols to monitor water quality, especially for the determination of VOCs and other dissolved gases, more quickly and efficiently than existing technologies. The methods will apply to wastewater management, lake/river water analysis, and monitoring of drinking water treatment plants.

MAP gas-phase extraction uses a unique energy transfer mechanism whereby chemical species that do not absorb microwaves well, e.g., VOCs, are energised by the transfer of energy from strongly microwave-absorbing substances, e.g., water. A MAP gas-phase prototype device is being evaluated for the extraction of VOCs, such as BTEX (benzene, toluene, and xylene), from contaminated water samples. Significant enhancement in response has been observed compared to conventional headspace analysis. Commercialisation activities will be undertaken next.

14.3 Removal of Contaminants from Soil Using the MAP Technology

The ETC has a program under way to evaluate the possibility of using MAP to decontaminate soils on a large scale. This project builds on knowledge acquired on the use of MAP for extracting organic compounds from soil for preparing analytical samples. This project is partially funded by the Federal Government's Program on Energy Research and Development (PERD). Of particular interest is the possibility that the MAP technology may be effective on contaminated soils that are normally difficult to treat, such as soils with a high clay, humic matter, or moisture content, or soils contaminated with a combination of contaminants or containing a high level of salts. As a result, various industrial parties from Canada and abroad have expressed interest in this technology.

Laboratory-scale testing has been done on the removal of PCBs, phenolic compounds, and PAH from soils. Tests were also performed to investigate the use of MAP for the cleanup of soils contaminated by missile fuels. These results showed that the increased efficiencies, shortened process times, and reduced energy requirements of the MAP technology could overcome some of the problems associated with current excavation and treatment technologies. More tests will be performed at the laboratory- and bench-scale levels to further evaluate the MAP soil treatment process.

14.4 Enhancement of MAP Extraction Efficiency Using CO_2 under Liquid and Supercritical Fluid Conditions for Industrial Purposes

Laboratory-scale tests have been performed to evaluate extractions using CO_2 with and without the addition of microwave exposure. Preliminary results using various plant materials show that combining MAP with liquid CO_2 conditions gives results similar to conventional CO_2 supercritical-fluid extraction conditions. Eliminating the requirement for high pressures associated with supercritical conditions greatly reduces the capital and operating costs of equipment.

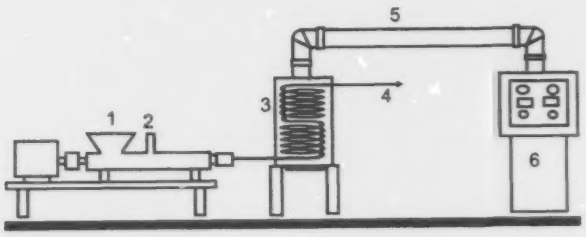
14.5 MAP Laboratory-scale Extraction Equipment

Commercial analytical-scale MAP units are manufactured and sold by the CEM Corporation (U.S.) and PROLABO (France). The CEM Corporation markets closed- and open-vessel systems and PROLABO markets open-vessels systems. These analytical microwave extractors are being sold under license to use Environment Canada's patented MAP technology. The ETC works closely with these companies on the development of these units and on research associated with the development of methods for their use.

15. Development of Industrial Applications of the MAP Technology

15.1 Design, Construction, Modification, and Testing of MAP Pilot Plant Process

In early 1994, the microwave portion of a MAP pilot-plant facility was designed and constructed. In the summer and fall of 1994, pre- and post-processing equipment was added to complete the pilot-plant process. This pilot-plant process consists of a 6-kW generator, a process cavity pump capable of continuously processing up to 900 L/h of slurry, and ancillary material handling and separation equipment. To date, various tests have been performed in the plant to determine the applicability of processing several products in a continuous flow, industrial system. Examples of the applications tested include the extraction of oils from oil seeds, natural pesticides from fresh plant material, and compounds having potential biological activity. The MAP pilot plant unit is shown in Figure 1.



1. Raw material feed 2. Solvent addition 3. Microwave process cavity 4. To separation and solvent recovery units 5. Waveguide 6. Microwave generator

Figure 1 MAP Pilot Plant Unit Schematic

15.2 Design and Construction of MAP Bench-scale Process

After the one-ton-slurry-per-hour MAP pilot-plant unit was completed in 1994, a bench-scale unit was designed and constructed to complement the larger pilot-plant. The bench-scale unit was built for testing smaller sample sizes and to facilitate more extensive process optimisation.

The design of the bench-scale unit was performed as part of a partnership established between the ETC and the French company SAIREM. The design of the unit took place in the 1995/96 fiscal year and the main components of the unit were constructed in the 1996/97 fiscal year. In the 1997/98 fiscal year, the system components were integrated to complete the unit and the unit was tested and optimised.

The bench-scale unit includes a 2-kW generator, a slurry-feed system, and an extraction cavity capable of handling conventional liquid solvents. The feed system for the unit consists of a solid continuous feed system and a solvent pump. The mixture of solvent and solid material enters the extraction cavity at one end. This cavity has an auger extraction chamber that allows for the continuous flow of the solvent/material slurry through the chamber and exposure of the slurry to

the microwaves transmitted from the slotted waveguide located beneath the chamber. There are plans to construct other cavities for the unit that will allow the use of liquefied gas solvents. The MAP bench-scale unit is shown in Figure 2.

The bench-scale system will be used to accelerate scale-up evaluations of the MAP process for many industrial applications. The large-scale applications of the technology promise many uses as a 'green' industrial process. The technology promises the elimination of dichloromethane from industrial extraction processing, while also reducing the energy consumption associated with current technologies.

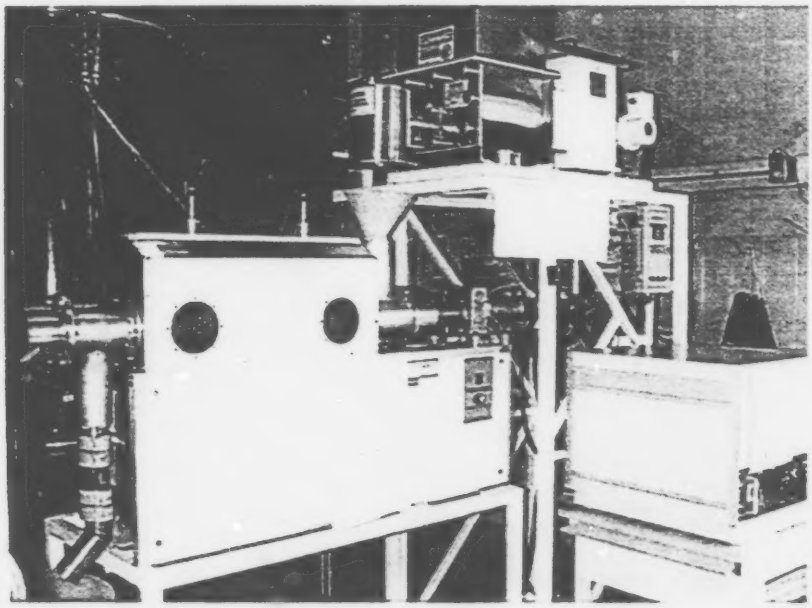


Figure 2 MAP Bench-scale Unit

15.3 MAP Industrial Product Development and Testing

More than 100 industrial applications of MAP have been tested to date, ranging from the extraction of high value-added substances such as ginseng to the recovery of valuable products from waste biomass, such as the treatment of waste cedar for the production of natural pesticides. These tests were performed at the laboratory-scale to determine extraction quality and efficiencies and to evaluate and optimise a variety of parameters for scale-up purposes. Some of the applications have also been tested at the larger scale.

16. MAP - A "Green" Technology

16.1 MAP and Greenhouse Gas Emissions

In 1999, Environment Canada entered into two important license agreements, furthering the use of the MAP technology with the aim of significantly reducing greenhouse gas emissions in industry. CanAmera Foods, Canada's largest processor of canola seeds, is licensed to use a MAP technology to extract canola oil. This is the first MAP license aimed specifically at industrial-scale production of a specific product. The application of the technology could significantly reduce greenhouse gas emissions from the Canadian oil-processing industrial sector. Another license agreement has been granted to B.C. Research Inc. for product development and large-scale industrial applications.

16.2 MAP/Climate Change Action Fund

The outcome of these new ventures led to a project funded through the "Technology for Early Action Measures" (TEAM) within the context of the Climate Change Action Fund (CCAF). This is a pilot project involving the MAP Division, CanAmera Foods, and B.C. Research Inc. and is based on meeting the challenge of climate change through reducing green house gas emissions. The project will contribute to the development of environmentally friendly and energy-efficient technologies that will help sustain economic growth and increase Canadian competitiveness – domestically and internationally. The collaboration will ensure that human health and the environment are protected and that the quality of life will be maintained for all Canadians.

The TEAM project is being carried out over three phases. The first phase, which has already been started, involves preliminary pilot-scale tests on canola plant material at Environment Canada's Environmental Technology Centre. In the second phase, which will start later this year, the testing will expand to include other plant materials such as flax and soya and will also look at the viability of replacing hexane with alternative solvents such as butane or propane. In Phase 3, CanAmera Foods will construct the first industrial-capacity processing plant to use the MAP technology.

The MAP technology for extracting edible oils is a clean, cost-efficient, and energy-efficient process that will enhance the international competitiveness of the Canadian food sector, contribute to reductions in greenhouse gases, and help to meet the challenge of climate change.

16.3 MAP/Collaborations

This section describes a few collaborations and achievements realized in the past two years in which the objective has been to further applications of MAP as a "clean process" technology.

The MAP Division and the Toxic Pollution Prevention Directorate joined forces in 1999 in a collaborative project agreement to develop "Green Chemistry" technologies. These two parties are keen to establish green chemistry as a pollution prevention approach to reducing the use and release of toxic chemicals in Canada. This project shows how green chemistry techniques can be applied in the Canadian context to achieve these objectives. This collaboration is furthering the development of MAP applications in two important industrial sectors, namely the synthesis industry for the pharmaceutical sector and the extraction industry for the food sector.

In collaboration with its French licensee SAIREM, the MAP Division has commissioned and received two new microwave cavities. This equipment will also be used as part of the MAP-led Climate Change Technology for Early Action Measures (TEAM) project. One microwave cavity will be used to assess the potential of substituting liquefied butane for hexane in the extraction of oilseeds. The other will be used to optimise energy application and potentially further reduce greenhouse gas emissions during the processing stage of edible oil manufacturing. This unit will also be used in research on other applications of microwaves.

16.4 MAP/Green Chemistry/Pollution Prevention

In summary, the MAP Division is continuing its efforts in those areas where it has an impact on some of the department's programs such as: Clean Processing/Clean Technology, Climate Change, Toxics, Emergency Response, Intellectual Property (IP) Management and Commercialisation, and Green Chemistry.

The Microwave-assisted Process is recognized as one of Canada's inventions of the 20th century and is listed on Environment Canada's "*A Century of Innovations: Federal Laboratories at Work*" poster.

17. Compliance Enforcement

17.1 Dioxins in Pulp and Paper Mill Effluents

The Pulp and Paper Mill Effluent Regulations prohibited the release of chlorinated dioxins and furans in pulp and paper mill effluents as of July 1, 1992. The control limit, based on level of quantification (LOQ), is 15 pg/L for 2,3,7,8-TCDD and 50 pg/L for 2,3,7,8-TCDF. Technical support for monitoring regulated compounds has been given to Regions by providing analysis of effluent samples collected by regional inspectors from selected pulp and paper mills for the monitoring of regulated compounds.

17.2 Analysis of PCBs

Various regulations under *CEPA* concerning polychlorinated biphenyls (PCBs) govern the production, use, storage, disposal, export, and discharge of PCB-containing materials. Technical support has been provided to the regions by analysing the legal samples submitted by regional inspectors for total PCBs.

17.3 Defoamer and Wood Chip Regulations

The Defoamer and Wood Chip Regulations are intended to control and prevent the formation of polychlorinated dioxins and furans and the discharge of these substances from pulp and paper mills that use a chlorine-bleaching process. The defoamers used by pulp and paper mills are limited to a maximum concentration of 10 ppb for dibenzodioxins and 40 ppb for dibenzofurans. Technical support has been provided to the regions by analysing the legal samples submitted by regional inspectors for the regulated compounds.

17.4 Analysis of Ozone-depleting Substances (ODS)

The ODS regulations govern the production and import/export of CFCs, HCFCs, Halons, Carbon tetrachloride, 1,1,1-trichloroethane, and methyl bromide. Technical support has been provided to the regions by analysing legal samples, consisting mostly of pressurized containers, for these regulated substances.

18. Support to the Development of Canada-Wide Standards (CWS) under the CCME's Federal-Provincial Harmonisation Accord

18.1 Petroleum Hydrocarbons (PHC) in Soil

18.1.1 Ecotoxicological Testing

A staff member of the Special Programs Division, Method Development and Applications Section, is a member of the PHS Ecolog Subcommittee. He is also acting as Environment Canada's representative on the PTAC/CAPP Ecological Acceptable Endpoints project, which is generating the soil toxicity test data for various hydrocarbon fractions. This toxicity information will be used by the Ecotag Subcommittee to generate proposed fraction-specific hydrocarbon criteria for use in CCME soil standard derivation.

18.1.2 Petroleum Hydrocarbons

An ETC staff member chaired the Analytical Method Technical Advisory Group. This group was charged to develop a method that best met the need of the standard, would reflect national capability, and ensure consistency. A consensus approach was used to develop the method. An inter-laboratory study was conducted in conjunction with CAEAL and the Ministère de l'environnement du Québec and the results were used to assess the performance of the draft method. The Analysis and Air Quality Division participated in the feasibility trial and the Emergencies Science Division participated in this study. A draft method was in the final stages of review by March 2000.

18.2 Particulate Matter (PM) and Ozone

ETC staff participated extensively in the development of the CWS for particulate matter and ozone. The choice of metrics for the CWS was based largely on data analysis carried out by ETC using collected data from the NAPS network. Staff attended public consultation sessions and responded to a variety of requests for special data analysis to support socio-economic analyses. Reports were prepared on rollback relationships for PM and ozone and on trends in PM and ozone.

18.2.1 Ambient Air Measurements for PM and Ozone

ETC staff prepared a plan for the enhancement of current monitoring activities for PM and ozone and participated in a federal provincial working group set up to address monitoring and reporting issues related to the CWS. The monitoring effort to control PM and ozone is extensive and data are routinely collected and disseminated through the NAPS program.

18.3 Benzene

ETC staff participated in the Development Committee for the Benzene Canada-Wide Standard, attending numerous meetings and participating in conference calls and a public consultation

session. A report was prepared under contract on emission trends for benzene and data were assembled for a socio-economic analysis of the benefits of reducing ambient air benzene levels.

18.3.1 Ambient Air Measurements for Benzene

Benzene is being measured at more than 40 sites across Canada. A report summarizing data collected from 1989 to 1998 was prepared and trends in ambient benzene levels were examined. This report has been posted on the website of the Canadian Council of Ministers of the Environment (CCME).

18.4 Polychlorinated Dibenzo Dioxins and Furans (PCDD/PCDF)

18.4.1 Ambient Air Measurements for PCDD/PCDF

PCDD and PCDF are being measured at 15 sites across Canada. A report summarizing measurements from 1989 to 1998 was prepared and distributed.

APPENDIX A — The Environmental Technology Centre (ETC) - Mission and Roles

MISSION

The mission of the Environmental Technology Centre is to support Environment Canada's national and international mandate for environmental protection by:

- developing and transferring knowledge in the areas of pollution measurement, prevention, control and remediation and new technology in the areas of air pollution and unplanned releases of oil and hazardous materials; and

- providing relevant specialised sampling and analytical expertise and services of the highest standards.

ROLES

- to support the regulatory role of Environment Canada by undertaking and promoting research and development (R&D), and technology advancement and transfer in measurement and control of air pollutant emissions, and in response to unplanned releases of oil and hazardous materials;

- to support pollution assessment and assist in solving environmental problems associated with specific sources of air pollution or spill/waste sites that have international, national, or regional implications by undertaking R&D based on in-house and external expertise and resources and co-operation with stakeholders;

- to manage or support Environment Canada's programs related to measurement and control of air pollution and releases of oil and hazardous materials by providing relevant sampling, analytical, and quality assurance expertise and services;

- to promote the better integration of economic and environmental issues and to foster a healthy and creative environmental protection industry in Canada through information and technology transfer, and by supporting the development of national and international technology standards and policies;

- to provide advice on environmental protection technology and emerging technical issues relating to air pollution and response to spills of oil and hazardous materials to the Department and other clients including the industry, provinces and territories, other R&D organisations, and the public; and

- to represent the Department and Canada in federal-provincial, national, and international environmental protection technology organisations and programs and act as full partners in the international community involved with the development and application of leading-edge technology and technical standards for environmental protection relating to air pollution and control of hazardous materials.

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APPENDIX F — Scientific Presentations

Chiu, C., W. Miles, A. Moudrakovskaia, and G. Poole, "Determination of Nitro-PAH in Ambient Air", presented at *Western Canada Trace Organics Workshop* in Calgary, AB, April, 1999.

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APPENDIX G -- ETC Staff Members

NAME	DIVISION	TELEPHONE #	FAX #	E-MAIL
ACKERMAN,Francine	ESD	(613) 990-9243	(613) 991-9485	ackerman.francine@etc.ec.gc.ca
BALGAVA, Viera	AAQD	(613) 990-6889	(613) 990-8568	balgava.viera@etc.ec.gc.ca
BARTON, Peter	ERMD	(613) 990-3723	(613) 952-1006	barton.peter@etc.ec.gc.ca
BÉLAND, Michel	BTES	(613) 990-7266	(613) 990-8861	beland.michel@etc.ec.gc.ca
BÉLANGER, Jacqueline	MAP	(613) 990-9239	(613) 990-2855	belanger.jacqueline@etc.ec.gc.ca
BERNARD, Joyce	BTES	(613) 990-7175	(613) 990-8861	bernard.joyce@etc.ec.gc.ca
BLENKINSOPP, Sandra	P&N	(780) 951-8705	(780) 495-2615	sandra.blenkinsopp@ec.gc.ca
BLOOM, Randy	BTES	(613) 990-3236	(613) 990-8861	bloom.randy@etc.ec.gc.ca
BOOTH, Robert	AAQD	(613) 990-6727	(613) 990-8568	booth.robert@etc.ec.gc.ca
BREALEY, George	ERMD	(613) 998-9590 ext. 232	(613) 952-1006	brealey.george@etc.ec.gc.ca
BROWN, Carl	ESD	(613) 991-1118	(613) 991-9485	brown.carl@etc.ec.gc.ca
BRUNET, Paul	AAQD	(613) 991-9460	(613) 990-8568	brunet.paul@etc.ec.gc.ca
BRYANT, Gale	AAQD	(613) 991-1448	(613) 990-8568	bryant.gale@etc.ec.gc.ca
BULLEN, Bob	DO	(613) 991-9653	(613) 998-1365	bullen.bob@etc.ec.gc.ca
BUMBACO, Mike	SPD	(613) 991-2387	(613) 998-0004	bumbaco.mike@etc.ec.gc.ca
CHARLES, Jennifer	ESD	(613) 990-3220	(613) 991-9485	charles.jennifer@etc.ec.gc.ca
CHIU, Chung	AAQD	(613) 990-8560	(613) 990-8568	chiu.chung@etc.ec.gc.ca
CIANCIARELLI, Dominic	ERMD	(613) 991-9457	(613) 952-1006	cianciarelli.dominic@etc.ec.gc.ca
CORKE, Doug	ERMD	(613) 998-9590 ext. 306	(613) 952-1006	corke.doug@etc.ec.gc.ca
CRAIG, Angus	ERMD	(613) 998-9590 ext. 224	(613) 952-1006	craig.angus@etc.ec.gc.ca
DABEK, Ewa	AAQD	(613) 990-3201	(613) 990-8568	dabek.eva@etc.ec.gc.ca
DANN, Tom	AAQD	(613) 991-9459	(613) 990-8568	dann.tom@etc.ec.gc.ca
DEWAR, Brad	BPS	(613) 998-0839	(613) 998-1062	dewar.brad@etc.ec.gc.ca
FEARN, Jim	ERMD	(613) 998-9590 ext. 227	(613) 952-1006	fearn.jim@etc.ec.gc.ca
FIELDHOUSE, Benjamin	ESD	(613) 991-1122	(613) 991-9485	fieldhouse.ben@etc.ec.gc.ca
FINGAS, Merv	ESD	(613) 998-9622	(613) 991-9485	fingas.merv@etc.ec.gc.ca
GAMBLE, Lloyd	ESD	(613) 991-1121	(613) 991-9485	gamble.lloyd@etc.ec.gc.ca
GOLDTHORP, Sandra	AAQD	(613) 991-1444	(613) 990-8568	goldthorp.sandra@etc.ec.gc.ca

GRAHAM, Lisa	ERMD	(613) 990-1270	(613) 952-1006	graham.lisa@etc.ec.gc.ca
GRAY, Dorothy	AAQD	(613) 998-3671	(613) 990-8568	gray.dorothy@etc.ec.gc.ca
GREER, Allen	ERMD	(613) 991-9467	(613) 952-1006	greer.allen@etc.ec.gc.ca
GRIBBON, Debi	ESD	(613) 990-8758	(613) 991-9485	gribbon.debi@etc.ec.gc.ca
HALMAN, Ron	AAQD	(613) 991-6218	(613) 990-8568	halman.ron@etc.ec.gc.ca
HENDREN, Fred	ERMD	(613) 990-5859	(613) 952-1006	hendren.fred@etc.ec.gc.ca
HENRY, Ina	ESD	(613) 990-3221	(613) 991-9485	henry.ina@etc.ec.gc.ca
HODGSON, Ross	AAQD	(613) 991-1443	(613) 990-8568	hodgson.ross@etc.ec.gc.ca
HOULE, Nicole	AAQD	(613) 991-5495	(613) 990-8568	houle.nicole@etc.ec.gc.ca
HOWES, Peter	ERMD	(613) 998-9590 ext. 223	(613) 952-1006	howes.peter@etc.ec.gc.ca
HOWES, Trish	DO	(613) 998-8918	(613) 998-0004	howes.trish@etc.ec.gc.ca
JOANETTE, Pierre	BTES	(613) 991-2970	(613) 990-8861	joanette.pierre@etc.ec.gc.ca
JOKUTY, Paula	ESD	(613) 991-1108	(613) 991-9485	jokuty.paula@etc.ec.gc.ca
KEMP, Robert	BPS	(613) 998-1053	(613) 998-1062	kemp.robert@etc.ec.gc.ca
KETCHESON, Kerry	ESD	(613) 991-4571	(613) 991-9485	ketcheson.kerry@etc.ec.gc.ca
LACHANCE, Edgar	DO	(613) 991-9714	(613) 998-1365	lachance.edgar@etc.ec.gc.ca
LAMBERT, Patrick	ESD	(613) 991-1110	(613) 991-9485	lambert.patrick@etc.ec.gc.ca
LANOY, Monique	AAQD	(613) 990-7639	(613) 990-8568	lanoy.monique@etc.ec.gc.ca
LAROCHE, Nanci	ESD	(613) 991-1114	(613) 991-9485	laroche.nanci@etc.ec.gc.ca
LAWUYI, Richard	ESD	(613) 991-4565	(613) 991-9485	lawuyi,richard@etc.ec.gc.ca
LEFEBVRE, Jacques	BPS	(613) 998-1053	(613) 998-1062	lefebvre.jacques@etc.ec.gc.ca
LI, Ken	ESD	(613) 990-3219	(613) 991-9485	li.ken@etc.ec.gc.ca
LISTER, Mike	AAQD	(613) 991-4228	(613) 990-8568	lister.mike@etc.ec.gc.ca
MacDONALD, Ross	BTES	(613) 990-3237	(613) 990-8861	macdonald.ross@etc.ec.gc.ca
MacGREGOR, Don	SPD	(613) 990-9540	(613) 998-0004	macgregor.don@etc.ec.gc.ca
MacILROY, Jeff	BPS	(613) 991-1754	(613) 998-1062	macilroy.jeff@etc.ec.gc.ca
MacINTOSH, Keith	BTES	(613) 998-0837	(613) 990-8861	macintosh.keith@etc.ec.gc.ca
MANN, Jeremy	ERMD	(613) 991-9468	(613) 952-1006	mann.jeremy@etc.ec.gc.ca
MANSFIELD, Brian	EETO	(613) 991-1843	(613) 998-1365	mansfield.brian@etc.ec.gc.ca
MAR, Jim	AAQD	(613) 991-1442	(613) 990-8568	mar.jim@etc.ec.gc.ca
MAROIS, Richard	ESD	(613) 991-1043	(613) 991-9485	marois.richard@etc.ec.gc.ca
MATHIEU, David	AAQD	(613) 991-5494	(613) 990-8568	mathieu.david@etc.ec.gc.ca

McGONEGAL, Willie	ERMD	(613) 998-9590 ext. 226	(613) 952-1006	mcgonegal.will@etc.ec.gc.ca
MEADOWS, Al	ERMD	(613) 991-9455	(613) 952-1006	meadows.al@etc.ec.gc.ca
MILES, Walter	AAQD	(613) 990-8562	(613) 990-8568	miles.walter@etc.ec.gc.ca
MOODIE, Ron	ERMD	(613) 998-9590 ext. 307	(613) 952-1006	moodie.ron@etc.ec.gc.ca
MULDOON, Pat	BTES	(613) 998-9218	(613) 990-8861	muldoon.pat@etc.ec.gc.ca
OLSON, Rebekah	BTES	(613) 990-6035	(613) 990-8861	olson.rebekah@etc.ec.gc.ca
PACAUD, George	SPD	(613) 990-9631	(613) 998-0004	pacaud.george@etc.ec.gc.ca
PARÉ, Jocelyn	MAP	(613) 990-9122	(613) 990-2855	pare.jocelyn@etc.ec.gc.ca
PAYNE, Francine	DO	(613) 991-5633	(613) 998-1365	payne.francine@etc.ec.gc.ca
PIECHOWSKI, Maria	AAQD	(613) 990-9127	(613) 990-8568	piechowski.maria@etc.ec.gc.ca
POOLE, Gary	AAQD	(613) 990-8564	(613) 990-8568	poole.gary@etc.ec.gc.ca
RIGDEN, Ian	ERMD	(613) 991-9464	(613) 952-1006	rigden.ian@etc.ec.gc.ca
ROSTKOWSKI, Jacek	ERMD	(613) 991-4871	(613) 952-1006	rostkowski.jacek@etc.ec.gc.ca
ROY, David	ESD	(613) 990-3222	(613) 991-9485	roy.david@etc.ec.gc.ca
SCROGGINS, Rick	SPD	(613) 990-8569	(613) 990-0173	scroggins.rick@etc.ec.gc.ca
SERGY, Gary	P&N	(780) 951-8855	(780) 495-2615	gary.sergy@ec.gc.ca
SHELTON, John	AAQD	(613) 991-9453	(613) 990-8568	shelton.john@etc.ec.gc.ca
SHERIDAN, Blair	AAQD	(613) 991-1445	(613) 990-8568	sheridan.blair@etc.ec.gc.ca
SOULIGNY, Michel	ERMD	(613) 998-9590 ext. 233	(613) 952-1006	souligny.michel@etc.ec.gc.ca
STEWART, Colin	BTES	(613) 991-6774	(613) 990-8861	stewart.colin@etc.ec.gc.ca
TARDIF, Mylaine	AAQD	(613) 990-8565	(613) 990-8568	tardif.mylaine@etc.ec.gc.ca
THIBERT, Benoît	AAQD	(613) 990-6148	(613) 990-8568	thibert.benoit@etc.ec.gc.ca
THORNTON, Dave	DO	(613) 991-9550	(613) 998-1365	thornton.david@etc.ec.gc.ca
TIGHE, Mike	BTES	(613) 952-2333	(613) 990-8861	tighe.mike@etc.ec.gc.ca
TOBIN, Dorothy	DO	(613) 998-1099	(613) 998-0004	tobin.dorothy@etc.ec.gc.ca
TREMBLAY, Claude	AAQD	(613) 991-1998	(613) 990-8568	tremblay.claude@etc.ec.gc.ca
TURLE, Richard	AAQD	(613) 990-8559	(613) 990-8568	turle.richard@etc.ec.gc.ca
WANG, Daniel	AAQD	(613) 991-9466	(613) 990-8568	wang.daniel@etc.ec.gc.ca
WANG, Zhendi	ESD	(613) 990-1597	(613) 991-9485	wang.zhendi@etc.ec.gc.ca
WHITE, Luc	ERMD	(613) 991-9461	(613) 952-1006	white.luc@etc.ec.gc.ca
WILLIAMS, Brian	ERMD	(613) 991-9458	(613) 952-1006	williams.brian@etc.ec.gc.ca
YEATMAN, Rick	AAQD	(613) 991-9454	(613) 990-8568	yeatman.rick@etc.ec.gc.ca

APPENDIX H - List of Acronyms (English and French)

ENGLISH		FRENCH	
AAFC	Agriculture and Agri-food Canada	Ministère de l'Agriculture et Agro-alimentaire Canada	AAC
AAQD	Analysis and Air Quality Division (Environmental Technology Centre)	Div. des analyses et qualité de l'air (Centre de technologie environnementale)	DAQA
ACOA	Atlantic Canada Opportunities Agency	Agence de promotion économique du Canada Atlantique	APECA
ADM	Assistant Deputy Minister	Sous-ministre adjoint	SMA
APEC	Asia-Pacific Economic Co-operation	Organisation de coopération économique Asie-Pacifique	APEC
ARET	Accelerated Reduction Elimination of Toxics	Accélération de la réduction et de l'élimination des toxiques	ARET
ASEAN	Association of SouthEast Asian Nations	Association des nations de l'Asie du Sud-Est	ANASE
ASTM	American Society for Testing and Materials	American Society for Testing and Materials	ASTM
A&WMA	Air and Waste Management Association	Air and Waste Management Association	AWMA
BPP	Biproducts and Processes Program	Programme des processus et produits biologiques	PPPB
BEPO	The Canadian Business Environmental Performance Office	Bureau de la performance environnementale des entreprises Canadiennes	BPEEC
BETO	Burlington Environmental Technology Office	Bureau de technologie environnementale de Burlington	BTEB
BN	Briefing Note	Note de breffage	NB
BTES	Building Technologies and Environmental Systems	Technologies et systèmes environnementaux des immeubles	TSEI

CAEAL	Canadian Association of Environmental Analytical Laboratories	Association canadienne des laboratoires d'analyse environnementale	ACLAE
CANSCET	Canada-Southern Cone Environmental Technology Initiative	Initiative de transfert des technologies environnementales Canada-Cône Sud	ITTECCS
CARB	California Air Resources Board	No translation	
CARE	Centre for Atmospheric Research Experiments	Centre for Atmospheric Research Experiments	CARE
CBS	Canadian Biotechnology Strategy	La stratégie canadienne pour la biotechnologie	SCB
CCHREI	Canadian Council for Human Resources in the Environment Industry	Conseil canadien des ressources humaines dans l'industrie de l'environnement	CCRHIE
CCIW	Canada Centre for Inland Waters	Centre canadien des eaux intérieures	CCEI
CCME	Canadian Council of Ministers of the Environment	Conseil Canadien des ministres de l'environnement	CCME
CEAA	*Canadian Environmental Assessment Act*	*Loi canadienne sur l'évaluation environnementale*	*LCEE*
CEBAN	Canadian Environmental Biotechnology Advisory Network	Comité consultatif canadien sur la biotechnologie environnementale	CEBAN
CEC	Commission of Environmental Co-operation	Commission de la coopération environnementale	CEC
CED	Canada Economic Development (formerly FORDQ)	Développement économique Canada pour les régions du Québec	DEC
CEIA	Canadian Environment Industry Association	Association canadienne des industries de l'environnement	ACIE
CEIS	Canadian Environmental Industry Strategy	Stratégie pour l'industrie canadienne de l'environnement	SICE
CEPA	*Canadian Environmental Protection Act*	*Loi canadienne sur la protection de l'environnement*	*LCPE*

CESPA	*Canadian Endangered Species Protection Act*	*Loi sur la protection des espèces en péril au Canada*	*LPEPC*
CET	Clean Environment Table	Table de l'environnement sain	TES
CETAC	Canadian Environmental Technology Advancement Centre	Centre canadien pour l'avancement des technologies environnementales	CCATE
CGSB	Canadian General Standards Board	Office des normes générales du Canada	ONGC
CIBS	Canada's International Business Strategy	Stratégie canadienne pour le commerce international	SCCI
CIDA	Canadian International Development Agency	Agence canadienne de développement international	ACDI
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora	Convention sur le commerce international des espèces de faune et de flore sauvages menacées d'extinction	CITES
CPPIC	Canadian Pollution Prevention Information Clearinghouse	Le centre canadien d'information sur la prévention de la pollution	CCIPP
CP/CT	Cleaner Production/Cleaner Technology	Méthodes de production/technologies propres	MP/TP
CTF-GEF	Consultant Trust Fund-Global Environmental Facility	Le fonds fiduciaire des consultants canadiens pour l'environnement mondial	FEM
CWS	Canada-Wide Standards	Standards pancanadiens	SP
DFAIT	Department of Foreign Affairs and International Trade	Ministère des affaires étrangères et du commerce international	MAECI
DFO	Department of Fisheries and Oceans	Ministère des pêches et des océans	MPO
DG	Director General	Directeur général	DG
DPR	Departmental Performance Report	Rapport ministériel sur le rendement	RMR
DSERT	Development and Demonstration of Site Remediation Technology Program	Programme de mise au point et de démonstration de techniques d'assainissement des lieux contaminés	DSERT

DSS	Decision Support Systems	Système d'aide à la décision	SAD
EA	Environmental Assessment	Évaluations environnementales	EE
EAB	Environmental Affairs Branch at Industry Canada	Bureau d'affaires environnementales à Industrie Canada	BAE
EARP	Environmental Assessment and Remediation Project	Projet d'évaluation et de restauration environnementale	PERE
EC (formerly DOE)	Environment Canada (formerly, Department of the Environment)	Environnement Canada (auparavant, ministère de l'environnement)	EC
ECEP	Environmental Centre of Excellence Project	Environmental Centre of Excellence Project	ECEP
ECS	Environmental Conservation Service	Service de la conservation de l'environnement	SCE
EED	Emergencies Engineering Division (of ETC, now SAIC Canada)	Division du génie des urgences (du CTE, maintenant SAIC Canada)	DGU
EMB	Environmental Management Board	Comité de gestion d'environnement Canada	CGEC
EMS	Environmental Management System	Système de gestion environnementale	SGE
EPP	Environmental Protection Program	Programme de la protection de l'environnement	PPE
EPS	Environmental Protection Service	Service de la protection de l'environnement	SPE
ERMD	Emissions Research and Measurement Division (of ETC)	Division de la recherche et mesure des émissions (du CTE)	DRME
ESD	Emergencies Science Division (of ETC)	Division des sciences d'intervention d'urgence (du CTE)	DSU
ESTAC	Environmental Science and Technology Alliance of Canada	L'Alliance Canadienne des Sciences et des Technologies de l'Environnement	ESTAC
ETAD	Environmental Technology Advancement Directorate	Direction générale pour l'avancement des technologies environnementales	DGATE
ETC	Environmental Technology Centre	Centre de technologie environnementale	CTE

ETLP	Environmental Technology Loan Program	Programme de prêts pour l'industrie de la technologie environnementale	PPITE
ETV	Environmental Technology Verification	Programme de vérification des technologies environnementales	VTE
GHG	Greenhouse Gas	Gaz à effet de serre	GES
GLP	Good Laboratory Practices	Bonnes pratiques de laboratoire	BPL
GOCO	Government Owned Contractor Operated	Biens immobiliers appartenant à l'état et exploités par le secteur privé	GOCO
H&S	Health and Safety	Santé et sécurité	S & S
HRDC	Human Resources Development Canada	Développement des resources humaines Canada	DRHC
IC	Industry Canada	Industrie Canada	IC
IDRC	International Development Research Canada	Centre de recherches pour le développement international	CRDI
IEMI	International Environmental Management Initiative	Initiative internationale de gestion de l'environnement	IIGE
IEYC	International Environmental Youth Corps	Service écojeunesse international	SEI
IFI	International Financial Institutions	Institutions financières internationales	IFI
IJC	International Joint Commission	Commission mixte internationale	CMI
IP	Intellectual Property	Propriété intellectuelle	PI
IPO	Intellectual Property Office	Bureau de la propriété intellectuelle	BPI
IRAP	Industrial Research Assistance Program	Programme d'aide à la recherche industrielle	PARI
ISO	International Organization for Standardization	Organisation internationale de normalisation	ISO
JPA	Joint Project Agreement	Projet conjoint ou entente relative à un projet conjoint	PC

LOI	Letter of Interest	Lettre d'intérêt	L.O.I.
LOQ	Level of Quantification	Niveau de dosage	NdM
MAP™	Microwave Assisted Process	Procédés assistés par micro-onde	MAP^MC
MAP Division	Microwave Assisted Process Division	Division des procédés assistés par micro-onde	Division MAP^MC
MENVIQ	Quebec Ministry of the Environment	Ministère de l'environnement du Québec	MENVIQ
MOU	Memorandum of Understanding	Protocole d'entente	PE
MP	Montreal Protocol	Protocole de Montréal	PM
MSC	Meteorological Service of Canada	Service Météorologique du Canada	SMC
MVSA	Motor Vehicle Safety Act	Loi sur la sécurité des véhicles automobiles	LSVA
NACAT	National Advisory Committee on Air Technologies	Comité consultatif national sur les technologies de l'air	CCNTA
NAAEC	North American Agreement on Environmental Cooperation	Accord nord-américain de coopération dans le domaine de l'environnement	ANACE
NAFTA	North American Free Trade Agreement	Accord de libre-échange nord-américain	ALÉNA
NAPS	National Air Pollution Surveillance	Réseau national de surveillance de la pollution atmosphérique	RNSPA
NCSRP	National Contaminated Sites Remediation Program	Le Programme national d'assainissement des lieux contaminés	PNALC
NETA-AC	National Environmental Technology Advancement Advisory Committee	Groupe de travail sur l'avancement des technologies de l'environnement	GT-ATE
NETA-WG	National Environmental Technology Advancement Working Group	Comité d'orientation des directeurs de l'avancement des technologies de l'environnement	COD-ATE
NGO	Non-governmental organization	Organisation non-gouvernementale	ONG
NHRI	National Hydrology Research Institute	Institut national de recherches en hydrologie	INRH
NOPP	National Office of Pollution Prevention	Bureau national de la prévention de la pollution	BNPP

NPRI	National Pollutant Release Inventory	Inventaire national des rejets de polluants	INRP
NRC	National Research Council	Conseil national de recherches du Canada	CNRC
NRCan	Natural Resources Canada	Ressources naturelles Canada	RNCan
NSERC	Natural Sciences and Engineering Research Council	Conseil de recherches en sciences naturelles et en génie	CRSNG
NWRI	National Water Research Institute	Institut national de recherches sur les eaux	INRE
OCEDCO	Ottawa-Carleton Economic Development Corporation	La Société d'expansion économique d'Ottawa-Carleton	SEEOC
OCETA	Ontario Centre for Environmental Technology Advancement	Ontario Centre for Environmental Technology Advancement	OCETA
ODS	Ozone Depleting Substances	Les substances appauvrissant la couche d'ozone	SACO
OECD	Organization for Economic Co-operation and Development	Organisation de coopération et de développement économique	OCDE
OGD	Other Government Departments	Autres ministères du gouvernement	AMG
OGEB	Oil, Gas and Energy Branch, EC	Direction du pétrole, du gaz et de l'énergie, EC	DPGE
PBT	Persistent Bioaccumulative Toxic substances	Substances persistantes, bioaccumulables et toxiques	PBT
PCB	Polychlorinated Biphenyls	Biphényles polychlorés	BPC
PCDD/PCDF	Polychlorinated Dibenzo Dioxins/Polychlorinated Dibenzofurans	Polychlorodibenzo-paradioxines/polychlorodibenzofurannes	PCP/PCDF
PEC	Pacific Environmental Centre	Centre environnemental du Pacifique	CEP
PERD	Program of Energy Research and Development	Programme de la recherche et du développement énergétique	PRDE
PHC	Petroleum Hydrocarbons in Soil	Hydrocarbures de pétrole dans le sol	HCP
PM	Particulate Matter	Particules	PM

POPs	Persistent Organic Pollutants	Polluants organiques persistants	POP
PRAS	Planning, Accountability and Reporting Structure	Structure de la planification des rapports et des sphères de responsabilité	SPRR
PSL	Priority Substances List	Liste des substances d'intérêt prioritaire	LSP
PROUD	Photo-Refractive Optical Ultrasonic Detector	Photo-Refractive Optical Ultrasonic Detector	PROUD
PWGSC	Public Works and Government Services Canada	Travaux publics et Services gouvernementaux	TPSGC
R&D	Research and Development	Recherches et développement	R & D
RDG	Regional Director General	Directeur général régional	DGR
RFP	Request for proposal	Demande de proposition	DP
RPP	Report on Plans and Priorities	Rapport sur les plans et les priorités	RPP
SAIC	Science Applications International Corporation (formerly, EED of ETC)	Science Applications International Corporation (auparavant, DUE du CTE)	SAIC
S&T	Science and Technology	Science et technologie	S & T
SCC	Standards Council of Canada	Le Conseil canadien des normes	CCN
SLV2000	St. Lawrence Vision 2000	Saint-Laurent Vision 2000	SLV2000
SMEs	Small and Medium-Sized Enterprises	Petites et moyennes entreprises	PME
SPD	Special Projects Division (of ETC)	Division des programmes spéciaux (du CTE)	DPS
TEAM	Technology Early Action Measures	Mesures d'action précoce en matière de technologie	TEAM
TIB	Technology and Industry Branch	Direction de la technologie et de l'industrie	DTI
TOS	Technology Outreach Section	Section de la mise en valeur de la technologie	TOS
TPC	Technology Partnerships Canada	Partenariat technologique Canada	PTC
TPPD	Toxic Pollution Prevention Directorate	Direction générale de la prévention de la pollution par des toxiques	DGPPT
TSMP	Toxic Substances Management Policy	La politique de gestion des substances toxiques	PGST

TSRI	Toxic Substances Research Initiative	L'initiative de recherches sur les substances toxiques	IRST
TTO	Technology Transfer Office	Bureau du transfert technologique	BTT
UCS	Universal Classification Standard	Norme générale de classification	NGC
UCS	Universal Classification System	Système général de classification	NGC
UNECE-LRTAP	United Nations Economic Commission for Europe - Long-range Transportation of Air Pollution	Commission économique des Nations Unies pour l'Europe - Transport à grande distance de la pollution atmosphérique	CEE-ONU-TGDPA
UNEP	United Nations Environment Programme	Programme des Nations Unies pour l'environnement	PNUE
USEPA	United States Environmental Protection Agency	United States Environmental Protection Agency	USEPA
VO	Environmental Industry Virtual Office	Bureau virtuel de l'industrie environnementale	BV
WAPPRIITA	*Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act*	*Loi sur la protection d'espèces animales ou végétales sauvages et la réglementation de leur commerce international et inter-provincial*	*WAPPRIITA*
WD	Western Economic Diversification	Diversification de l'économie de l'Ouest	DEO
WTC	Wastewater Technology Centre	Centre de technologie des eaux usées	CTEU